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This study is designated a Metropolitan/Regional Plan, and proposes the most advantageous and economically feasible plan for protection and enhancement of the water quality of the Lake of the Ozarks. Its scope includes review of available reports on population, land use, recreation and flood control, and evaluation of these relative to potential impact on water quality; review of existing domestic and industrial and agricultural waste sources and treatment facilities; impact of wastes on the areal waters relative to existing state water quality standards; existing areal governmental entities and their structures relative to present and potential wastewater management programs; identification of unsewered and combined sewered urban areas and an evaluation of their potential water quality impact; development and implementation of a water sampling and monitoring program for the Lake of the Ozarks; development of alternative management programs, including priorities, for meeting water quality objectives.

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LAKE OF THE OZARKS

WATER QUALITY
MANAGEMENT PLAN

1974

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

REGION VII - KANSAS CITY, MISSOURI

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LAKE OF THE OZARKS

WATER QUALITY
MANAGEMENT PLAN

By the staff of the Program Planning and Analysis Branch, Management Division

REGION VII

U.S. ENVIRONMENTAL PROTECTION AGENCY

KANSAS CITY, MISSOURI

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The following federal, state and local agencies also contributed to the study: the U.S. Geological Survey; the U.S. Corps of Engineers; the Federal Power Commission; the Farmers Home Administration; the Soil Conservation Service, the U.S. Department of Agriculture; the Missouri Conservation Commission; the Missouri Department of Community Affairs; the Missouri Water Resources Board; the University of Missouri Extension Division; the Missouri State Division of Health; the Missouri Boat Commission; the Missouri Park Board; and the Missouri Tourism Commission.

FOREWORD

This study, conducted by the Program Planning Branch of the Environmental Protection Agency, Region VII, proposes the most advantageous and economically feasible plan for protection and enhancement of the water quality of the Lake of the Ozarks.

Entitled the Lake of the Ozarks Water Quality Management Plan, the proposal is valid for the Lake of the Ozarks Region only. It is directed toward the area's unique problems and, consequently, is not intended for general application. U.S. Public Law 84-660, Section 3(a), et seq., approved July 9, 1956, authorized funding of the study.

CHAPTER I

SUMMARY

The major obstacle to maximum protection and enhancement of the water quality of the Lake of the Ozarks which emerged as a result of this study is the absence of a system to collect and carry wastes to treatment sites. For implementation of an effective area-wide wastewater management system, various local governmental administrative problems must be solved.

The Statutes of Missouri authorize local government to construct and operate wastewater collection and treatment systems. However, there has been no indication of sufficient public awareness of the need for a system and, at this time, public sentiment does not lend support to the idea of a possible benefit or sanitary district.

Most of the Lake shore residents occupy homes on individual lots in unincorporated segments of the Lake of the Ozarks Study Area. With the exception of very small incorporated areas, the agency responsible for governmental functions in the Region is the county. Since only a small portion of each county is involved, and many lot owners are nonresidents who work away from the area, the county governments have not been compelled to furnish the normally expected utilitarian services. These include water supply, streets and roads, sewerage, lighting, zoning protection and, of course, police and fire protection. Individuals occupying the recreation areas have not demanded such services during their limited periods at the Lake.

Methods of financing a system to prevent a financial burden to residents who are not discharging wastes to the Lake waters are discussed in Chapter XIV of this study. Chapter XI proposes a system within the financial capabilities of users, with costs not prohibitive to the use of the Lake as a vacation and recreation area.

The collection system proposed is new and innovative and departs greatly from conventional systems. Conventional systems operate by gravity with pumping in a few locations only, while the system recommended is a completely pressurized one operated entirely by individual pumps at or near residences and commercial buildings. Although this system has not been widely used, it has been thoroughly tested and approved by federal and state authorities.

The proposed treatment system is a conventional one which has stood the test of time as well as that of widespread use. It produces a treated wastewater which will not degrade the Lake waters biologically, chemically, physically, or bacteriologically.

Detailed surveys of the few waste treatment schemes, in the area's communities and larger resorts revealed deficiencies which can easily be corrected. State and federal funds are available to assist in necessary correctional work at publicly owned facilities. The large, privately owned resorts may use tax incentives to help defray costs. Technical advice from state and federal agencies is available to all persons, communities or corporations to assist in obtaining improved treatment.

Surveys discussed in Chapter IV indicate the water quality of the Lake is good. A few locations showed degradation as a by-product of human activity during the high use periods, especially on weekends and during summer months. While such degradation was readily detectable, there was no indication the Lake was seriously polluted or contaminated. However, the present degree of degradation indicates a trend in water quality with increased use. Therefore, this study proposes preventive measures for adequate waste collection and treatment for implementation in the near future, before more serious degradation occurs.

In conclusion, the effects of the Harry S. Truman Dam and Reservoir, with its hydro-electric power generating facilities should be mentioned. Expectations are the Harry S. Truman installation will improve the physical quality of the water--less silt and clay will enter the Lake, with resulting cleaner and clearer water. No detectable changes in chemical, biological, or bacteriological content are anticipated.

Temperatures will not be affected. Another effect which is not a water quality consideration will be water level changes due to power facility operation in the upper end of the Lake. This will seriously affect the Lake and riparian users. The reader is referred to the Environmental Impact Statement prepared by the Corps of Engineers, U.S. Army, for further discussion of this subject.[1]

CHAPTER II

INTRODUCTION

IMPACT OF WATER QUALITY

Water quality may be evaluated in terms of its effect on (1) fish and wildlife, (2) recreation potential, (3) public health, or (4) area development. Historically, is impact on public health as well as on fish and wildlife has been the dominant consideration. Extensive research has documented the adverse effect of water quality degradation on desirable fish and wildlife populations, and the increased public health hazards associated with degraded water quality. Only recently have recreation potential and area development been considered in assessment of water quality impact. Under present economic conditions, however, the quality of available waters may be of greater significance than the more traditional quantity.

Abundant high quality water is an economic incentive to domestic and industrial growth. High quality usually is associated with lower raw water treatment costs. Of greater importance may be the environmental and recreational inducements communities and industries offer prospective residents and employees. The present trend toward a shorter work week and more leisure time makes the availability of water oriented recreational facilities and a clean environment increasingly dominant factors in individual and corporate relocation plans. Within the Study Area, the trend toward water oriented living is shown by the many lake shore housing developments currently planned.

Water based recreational activities are especially sensitive to water quality. Objectionable odors, turbidity, oil slicks, suspended or floating materials, color and fungus growths--all contribute to a decline in water sports. Such a decrease in activity is accompanied by a corresponding increase in protests from both public and private sectors and, frequently, noticeable decreases in total community capital outlay for water oriented activity.

BACKGROUND

Impetus for this study originated with the Federal Water Quality Act of 1965, et seq. That act and subsequent federal regulations stipulate the development of regional water quality management plans for eligibility for federal grant monies funding pollution abatement projects. Regional plans may be either basin plans or metropolitan regional plans. This study on the Lake of the Ozarks is designated a Metropolitan/Regional Plan. (The Clean Water Act of 1972 modified original requirements, and this study reflects those modifications.)

PURPOSE AND SCOPE

The purpose of this report is to develop a comprehensive metropolitan/regional plan and implementation program for sewerage facilities within the Lake of the Ozarks Study Area for the future (circa 1990). As a result of this planning effort, water quality requirements can be met and future degradation of water resources in the Study Area prevented. Development of land and water resources must include constraints which will prevent degradation of these resources.

The following plan is intended as a guide for evaluating proposed housing, industrial and recreational projects, and will identify needed constraints to attain environmental goals. The scope of the study includes the following:

1. Development and implementation of a water sampling and monitoring program in the Study Area.

2. Review of available reports on population, land use, recreation and flood control, and evaluation of these relative to potential impact on water quality. Where feasible, the available data have been summarized for presentation and included in this report.

3. Location and evaluation of all domestic and industrial waste sources and waste treatment facilities.

4. Identification of unsewered and combined sewered urban areas and an evaluation of their potential water quality impact.

5. Identification and evaluation of agricultural waste sources.

6. Review of existing areal governmental entities and their organizational and financial structures relative to present and potential wastewater management programs.

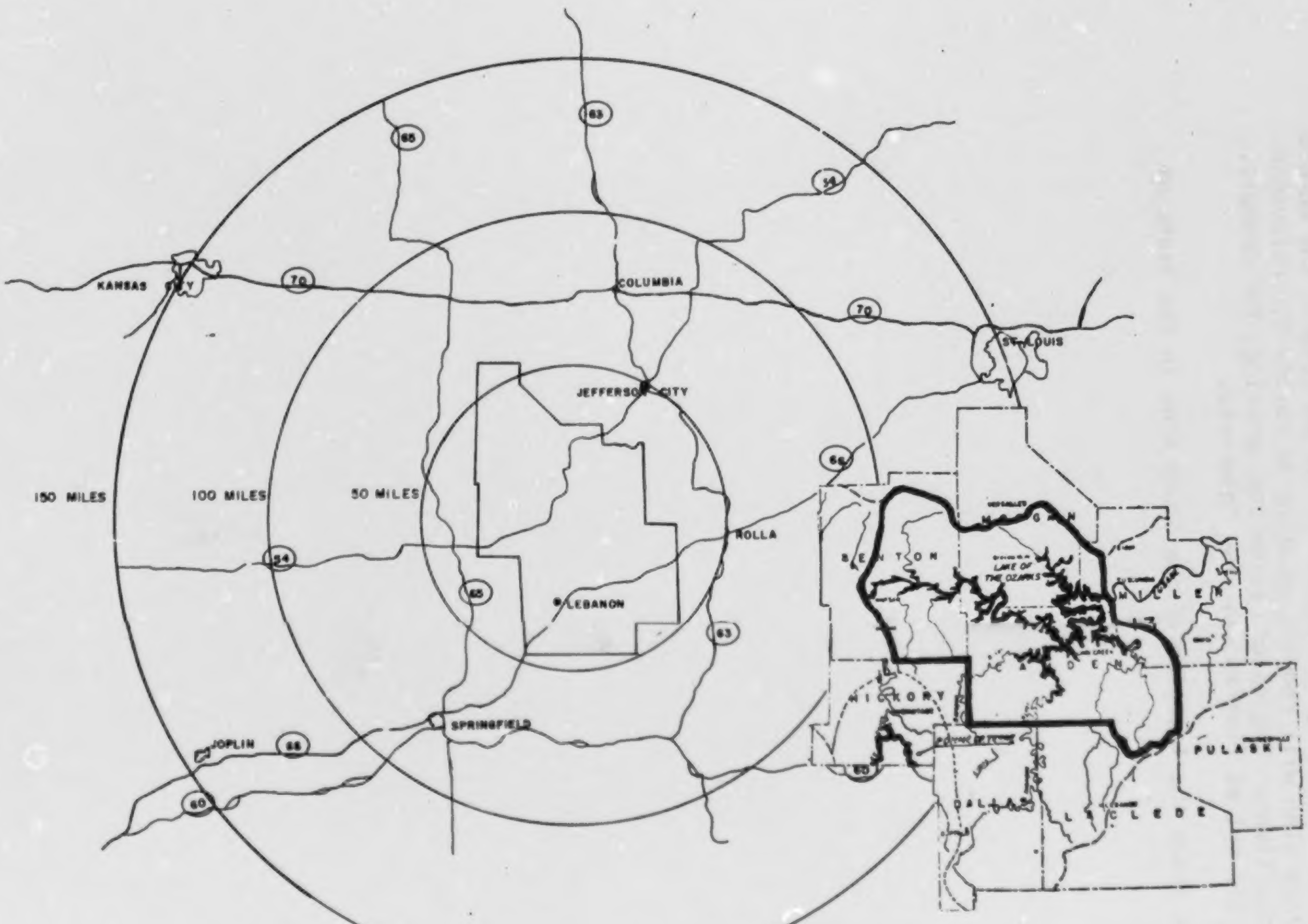
7. Assessment of the present and future magnitude of the urban, industrial and agricultural wastes originating within the Study Area and their impact on the areal waters relative to existing state water quality standards.

8. Development of alternative management programs, including priorities, for meeting water quality objectives.

The Lake of the Ozarks Water Quality Management Plan is a broad-based study which can provide a basis for more detailed planning of sewerage facilities to accommodate future requirements. Because of its broad scope, no field surveying, subsurface borings, or flow gagings were undertaken or required to formulate the study's recommendations. A considerable amount of previously analyzed information was utilized.

The Lake of the Ozarks is a dynamic, growing area and its exact sewerage needs through an entire twenty year period (circa 1990) are difficult to project with great accuracy. In the future, the comprehensive sewerage plan will require updating to assure its relevance to current conditions. Suggested review and updating, for example, would be carried out at five to ten year intervals.

Figure I shows the location of the Study Area in the State of Missouri.



SOURCE
Lake of the Ozarks Regional Planning Commission
Preliminary Water & Sewer Report (undated)

FIGURE 1
LOCATION MAP
STUDY AREA - LAKE OF THE OZARKS REGION

CHAPTER III

STUDY AREA DESCRIPTION

STUDY AREA BOUNDARIES

The Study Area comprises the Lake of the Ozarks and related land development near the shore. Lands exclusively for nonwater uses were considered separately from present and projected developments for water oriented activities. This separation is approximately 0.5 mile from the Lake shoreline established by pool elevation of 660 feet above mean sea level.

PHYSICAL DESCRIPTION

1. Geography. The Marais des Cygnes River, the largest and longest tributary of the Osage River, originates in east-central Kansas and flows eastward to its confluence with the Little Osage River to form the Osage River. The Osage River Basin has a drainage area of 15,300 square miles, 4,300 of which are in Kansas and 11,000 in Missouri. Bagnell Dam, forming the Lake of the Ozarks, controls 14,000 square miles of the basin.

2. Geology. The Osage River Basin lies in two physiographic provinces. The eastern part is in the Ozark Plateau, while the western part is located in the Osage Plains. Twelve major rock formations are exposed in the basin and can be roughly related to the topography and soils. In order, oldest to most recent and lower basin to headwaters, are the Procter Limestone of Cambrian Age; the Gasconade Dolomite, the Roubidoux Sandstone, and the Jefferson City Formation of Ordovician Age; undifferentiated limestones of Mississippian Age; the Henrietta, Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee formations of Pennsylvanian Age.

3. Topography. The Osage Plains, the western part of the basin above Osceola, Missouri, consists of gently rolling to hilly uplands, while the eastern section is in the rough and quite hilly Ozarks Plateau. Elevations above mean sea level range from 520 feet at the mouth to 1,450 feet at the headwaters. Maximum local relief is approximately 450 feet in the eastern part and about 200 feet in the western portion.

4. Soils. Basin soils are residual from sandstone, shale, limestone and cherty limestone, with alluvial soils in the river flood plains. Soils in the Osage Plains area above Osceola are residual from shale, sandstones, and limestones and include the Summit, Bates, Boone, Oswago, Pettis, Cherokee, and Crawford Soils. In the eastern part of the basin below Osceola, the soils are derived from cherty limestone and include the Clarksville, Crawford, Decatur, Eldorado, Lebanon, Huntingdon, and Gasconade series. The alluvial soils do not vary a great deal within

the two soil provinces. They are of quite recent origin and are composed of hydraulically reworked materials. All soils in the Osage River Basin are of varying clay content with resulting impervious subsoil layers which hold the infiltration rate to very low values.

5. Climate. The Osage River Basin lies in the humid zone and experiences a wide range of climatic conditions. Normal precipitation ranges from 32 inches in the west, or headwaters portion, to 40 inches in the southeastern, or lower portion of the basin. Temperatures recorded at Topeka, Kansas, near the headwaters, range from 109° F. to -21° F. Temperatures recorded at Bagnell Dam, near the mouth, range from 104° F. to -10° F.

6. Runoff. The Osage River flows exhibit great variations. The average annual discharge of the Osage River at St. Thomas, Missouri, 38 miles downstream of Bagnell Dam, from 1935 to 1969 was 9,735 c.f.s., or 9.1 inches of runoff. However, the variation was from 1.2 to 23.3 inches. The average annual discharge of the Osage River at Osceola, Missouri, located approximately 150 miles upstream from the dam, from 1920 to 1969 was 5,008 c.f.s, or 8.2 inches of runoff. Snowfall is not important as a contributor to runoff.

7. Hydrologic and Meterologic Data. The locations of the reservoir and water quality observation (sampling) stations are shown in Figure II. There are 28 stream gaging stations and two reservoir stage stations in the Osage River Basin for which data are published by the United States Geological Survey. All but three of the stations are at or above Bagnell Dam. A network of observation stations collects weather data throughout the basin. For a number of years, pan evaporation observations have been carried out at the dam during all but the winter months.

8. Groundwater. Groundwater in the Osage River Basin is rather limited, especially in the western portion of the basin. In the eastern portion, it is generally adequate for domestic needs. A strip runs across the basin from Nevada, Missouri to Warrensburg, Missouri, along which deep wells yield water with a high chloride content.

9. Upstream Reservoirs. Three upstream reservoirs, controlling a drainage area of 2,093 square miles, have been completed, and six additional reservoirs are authorized. Three are in the planning or construction stage.

10. Irrigation. Very little irrigation is carried on in the Osage River Basin. However, there appears to be increased interest in the irrigation potential of the upper basin.

11. Mining and Industrial Operations. Strip mining and underground coal mining are important parts of the basin economy which have adversely affected water quality. Basin industry consists mainly of the processing of agricultural products. Around the reservoir, there are practically no agricultural activities.

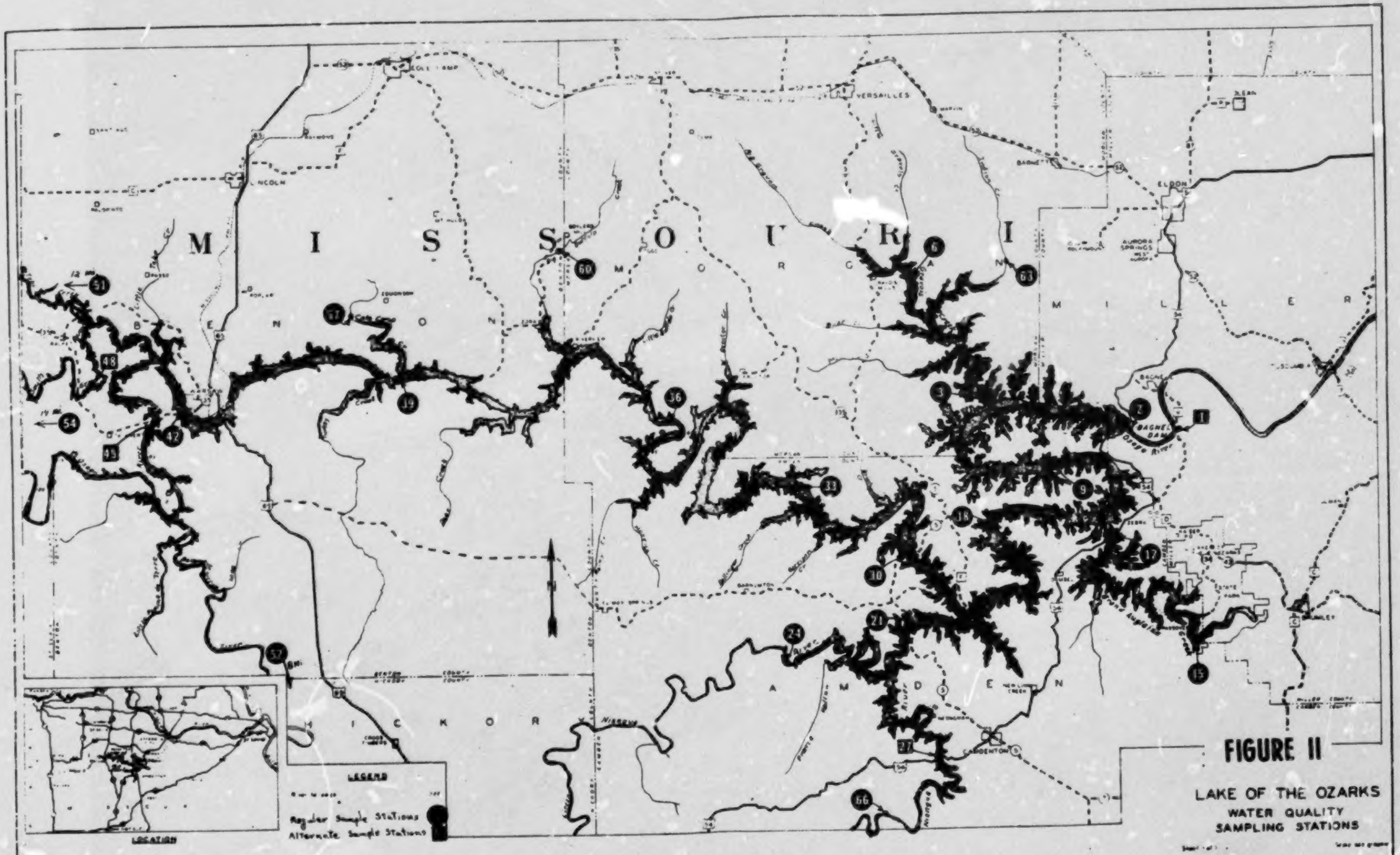
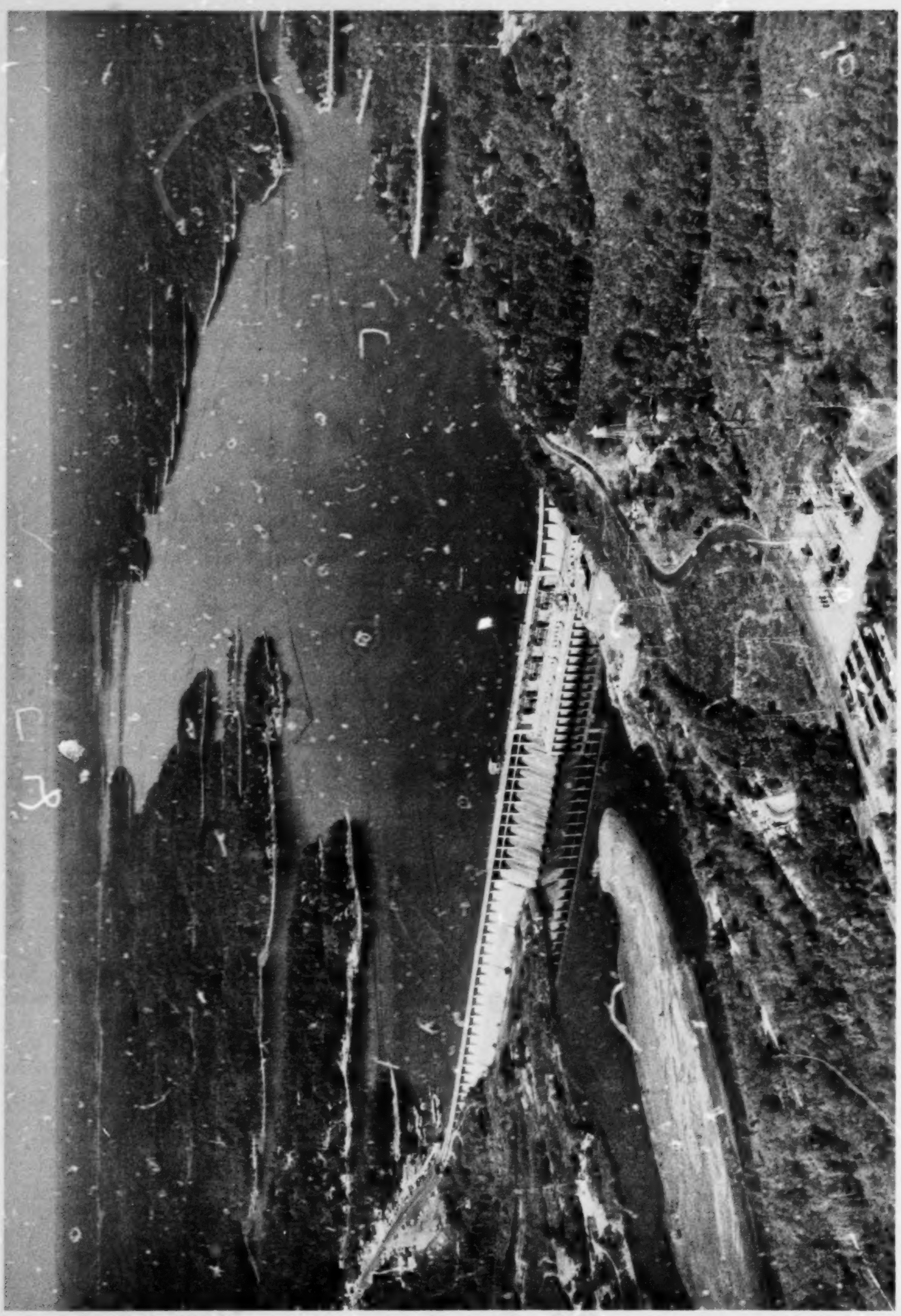


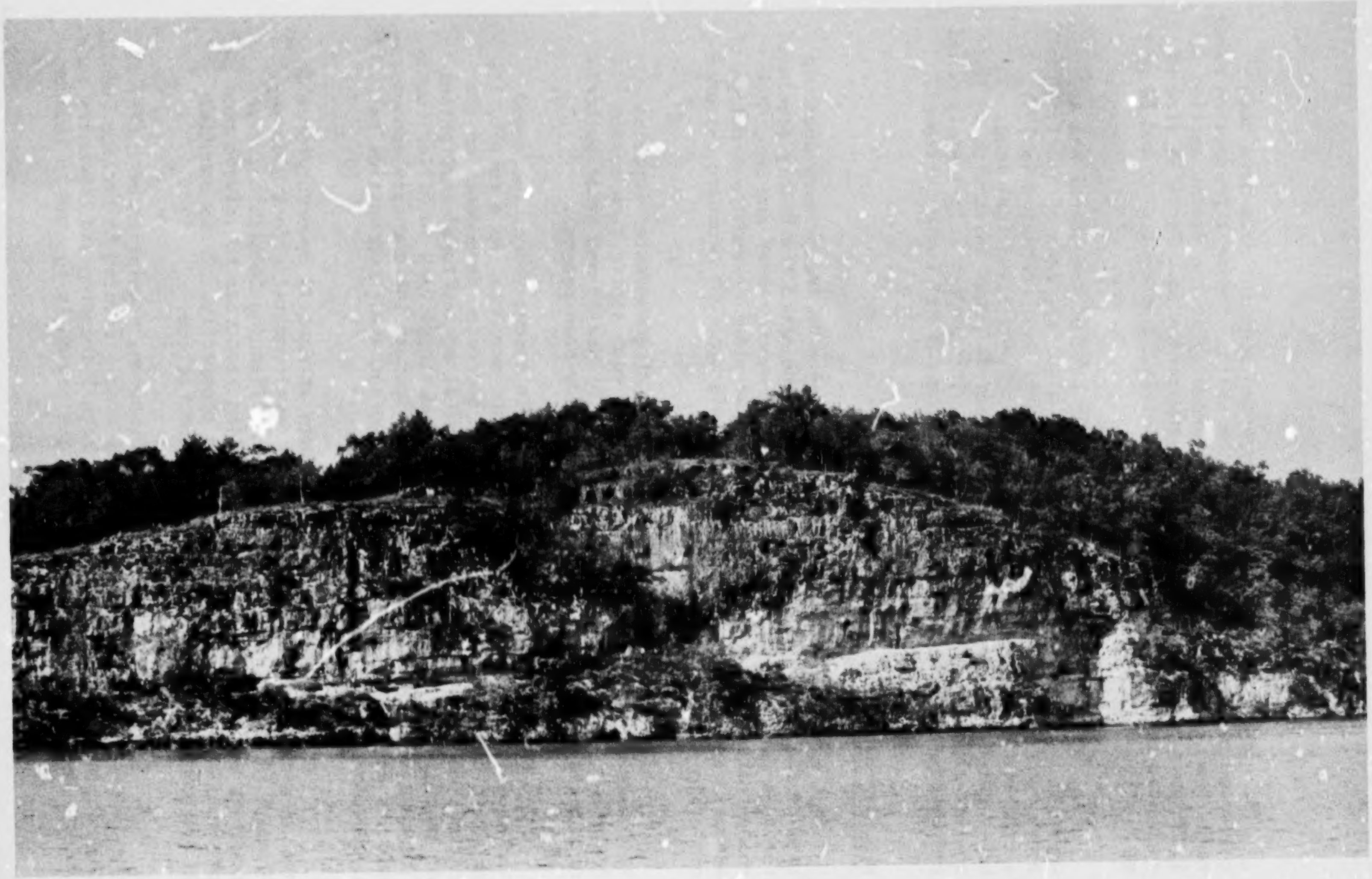
FIGURE II

LAKE OF THE OZARKS
WATER QUALITY
SAMPLING STATIONS

SOURCE U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VII 1971



Bagnell Dam, owned by Union Electric Company of St. Louis, Missouri, and the Lake of the Ozarks. (Photo by: Missouri Tourism Commission)



Typical limestone bluff along the Lake of the Ozarks. Note the lack of a soil profile which causes problems of trench excavation for sewer and water lines. (Photo by: Don Wooldridge, Missouri Department of Conservation)

12. Sediment. Since 1942, suspended sediment data have been collected at various locations in the basin. Sediment production rates range from 200 tons per square mile annually in the Ozarks section to 1,000 tons per square mile in the headwaters area. Particle size of suspended sediment indicates approximately 50 percent clay and 50 percent silt.

13. Pertinent Reservoir Data. The Lake of the Ozarks has a capacity of about 2,000,000 acre-feet, a surface area of nearly 60,000 acres, and a length of 129 miles. Bagnell Dam, completed in 1931, is a concrete gravity structure 148 feet high and 2,543 feet long. It has a gated spillway and eight hydroelectric power units with an installed capacity of 172,000 kilowatts. The project is privately owned and operated by the Union Electric Company of St. Louis, Missouri.

ECONOMIC DEVELOPMENT

1. Existing Economic Base. Recreation is the primary economic base of the area. Though parts of the lake shore are highly developed for this purpose, a potential exists for even greater and more highly concentrated development. Without proper planning and construction of adequate sewer and water facilities, this apparent economic resource could, in effect, become a liability.

The potential for contamination of groundwater supplies increases with each new well drilled and each septic tank system installed. The Missouri State Division of Health and other authorities believe a dangerous stage has already been reached.

2. Future Economic Development. In recent years, increased industrial development has stimulated the economy. As a result, the economic base has been broadened, with decreased dependence on the recreation industry as well as on marginal agricultural enterprises. Of special significance is the Eldon Industrial Park in Miller County. The development will add considerable vigor to the county's economy, and its benefits will undoubtedly encourage other communities to undertake similar projects.

A more intangible, but perhaps an equally powerful force in the area's economy, is the organized developmental effort underway. Through the Lake of the Ozarks Regional Planning Commission, five counties are working together, combining resources to solve common problems and to increase the region's prosperity. These counties are Morgan, Miller, Camden, Pulaski and Laclede.

3. Trade Centers. The City of Lebanon, population of 8,616, is the largest trade center in the Study Area. Located in Laclede County, the city offers a complete range of retail shopping and community services. One of the two hospitals in the region is located in Lebanon.

Other principal trade centers in the planning area are Waynesville and St. Robert in Pulaski County, with respective census populations of 3,375 and 1,279; Eldon in Miller County, population of 3,520; and Versailles in Morgan County with a population of 2,244.

Springfield (population, 120,096), located 35 miles southwest of Lebanon, offers a broader range of retail trade opportunities, as well as medical and dental services and a four year state college to residents of the planning area's southern portion. Sedalia (population, 22,847) and Jefferson City (population, 32,407) provide the extra services for residents of the northern section of the planning area.

Because of its distance from and travel time to large urban areas, the planning area is isolated from most metropolitan influences. St. Louis and Kansas City exert moderate influence on Lake of the Ozarks residents with the leisure and means to travel. Many residents, originally from metropolitan centers, shop at their favorite stores in the cities. The major newspapers of Kansas City, St. Louis and Springfield provide metropolitan news coverage. Specialized medical services, cultural and sporting events, national and international airline services are available in these areas, with Springfield exerting the greatest influence because of its proximity. However, the distance of these cities from the planning area is too great for commuter employment opportunities.

4. Highway Transportation. The present highway system in the five counties is generally adequate, although deficiencies exist in a few areas. The roads which carry recreational traffic are most in need of upgrading.

Figure III shows the locations of regional improvements planned during a five year period, 1970-1975.

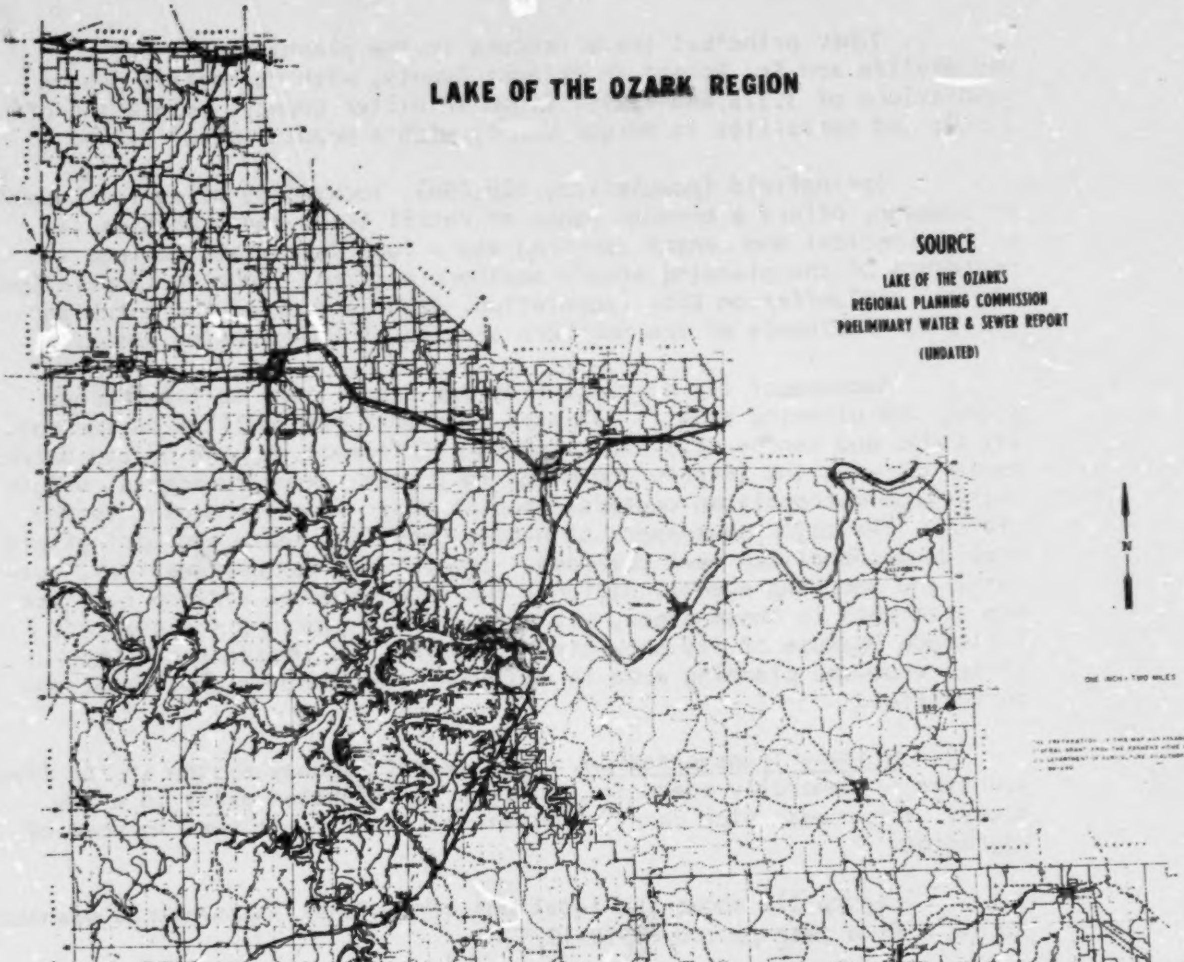
In Camden County, Highway 54 will be relocated from Route A east to the county line. A new bridge will be built across the lake, probably through state park property. No other major improvements are planned for Camden County. A study of Highway 5 south to Lebanon is underway at the present time.

In Miller County, Highway 54 is the main project. A by-pass of Eldon is planned with a new interchange at Highway 52, and 52 will be extended to Eldon by relocation. From Bagnell to the interchange at 52, 54 will be a four lane divided highway, and from the junction of Route FF to the county line, 54 will also be a divided highway.

In Morgan County, two bridge replacements are planned east of Stover, with one west of Stover on 52. Highway 50, located in Morgan County, will be relocated to the south of the present location.

Traffic volume on major highways increased over 34 percent in the period 1967-1970. A slightly smaller increase has occurred on

LAKE OF THE OZARK REGION


N
ONE INCH = TWO MILES
LEGEND
PROPOSED HIGHWAY IMPROVEMENTS
RAIL TRANSPORT FACILITIES
U.S. NUMBERED HIGHWAY
STATE NUMBERED HIGHWAY
1970 AVERAGE 24 HOUR DAILY TRAFFIC
AIRPORTS
COMMERCIAL CAPABILITIES
INTERMEDIATE CAPABILITIES

SOURCE

LAKE OF THE OZARKS
REGIONAL PLANNING COMMISSION
PRELIMINARY WATER & SEWER REPORT
(UNDATED)

FIGURE III

Reproduced from
best available copy.

the other state highways, with a corresponding increase on the county roads serving the Lake area. Very little change in the traffic volume has occurred on other county highways.

5. Railroad Transportation. The rail transportation for the five-county planning area is quite inadequate. Railroads operating in the region are: the Chicago, Rock Island and Pacific Railroad which serves Stover, Versailles, Barnett and Eldon; the St. Louis-San Francisco Railway, which serves Conway, Phillipsburg, Lebanon, Stoutland, Richland, Crocker and Dixon; and the Missouri Pacific Railway which serves Syracuse. Figure III shows the location of these railways in the region.

6. Air Transportation. Air carrier service is available at Lee C. Fine Airport, and at Forney Field. Charter service is available at Lebanon, Lee C. Fine, Eldon, Versailles and Linn Creek. Public airports are also located at Versailles, Wulff Harbor, Eldon, Camdenton, Richland, and Linn Creek. These airports are used for private flying and other nonscheduled flights. Figure III shows the location of these airports. No major air carriers serve the Study Area.

7. Bus Transportation. Missouri Transit Lines, Inc. operates from Ottumwa, Iowa to Springfield, Missouri, via Jefferson City, Camdenton, and Lebanon. This company also provides direct service from Jefferson City to Fort Leonard Wood via Eugene and Crocker. Missouri Transit has authority to originate a charter coach movement at an on-line point. Missouri Transit recently purchased the bus operation between Kansas City and Fort Leonard Wood which will also serve Clinton and Lebanon.

Greyhound Lines, Inc., operates 15 runs per day in each direction between St. Louis and Joplin via Fort Leonard Wood, Lebanon and Springfield. Greyhound has charter rights at all points in Missouri.

American Buslines, Inc. (Trailways) operates on the same route as Greyhound over U.S. 66 and I-44. This company operates two daily runs which serve Lebanon, Waynesville and Fort Leonard Wood.

Williams Bus Lines provides bus service between Waynesville and Fort Leonard Wood. It operates two daily round-trip runs to Rolla and has charter rights at Fort Leonard Wood and at Waynesville.

Midwest Buslines, Inc. (Trailways) operates between St. Louis and Kansas City over U.S. Highway 50, crossing through the northeastern tip of Morgan County at Syracuse.

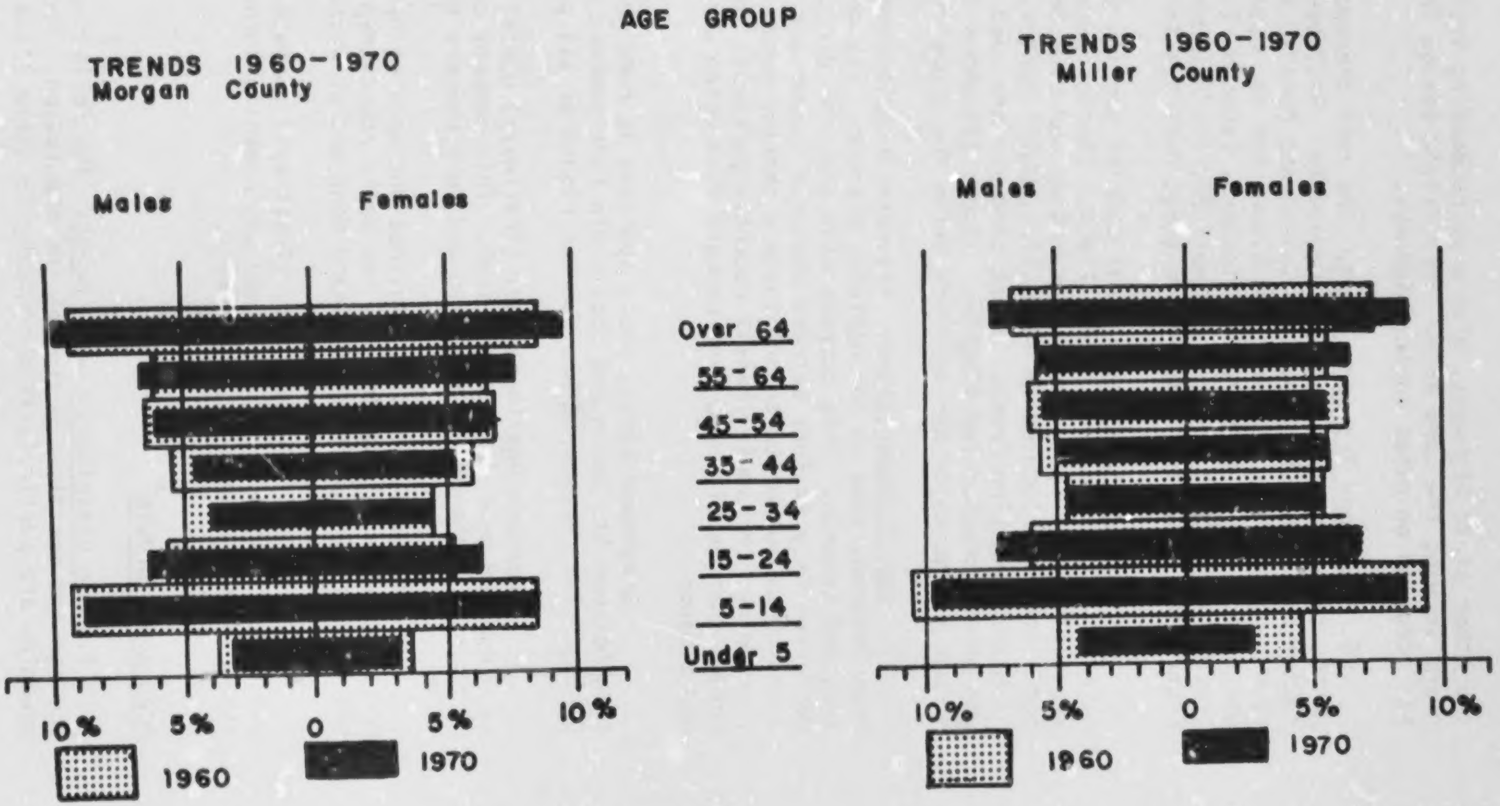
POPULATION GROWTH

1. Age Distribution and Change. The following charts illustrate the age and sex distribution of the population. Four levels on the pyramids are particularly noteworthy in Table III-A.

TRENDS AND COMPARISONS OF AGE-SEX DISTRIBUTION

1960-1970

TABLE III-A



SOURCE : LAKE OF THE OZARKS REGIONAL PLANNING COMMISSION PRELIMINARY WATER & SEWER REPORT (undated)

TRENDS AND COMPARISONS OF AGE-SEX DISTRIBUTION

1960-1970

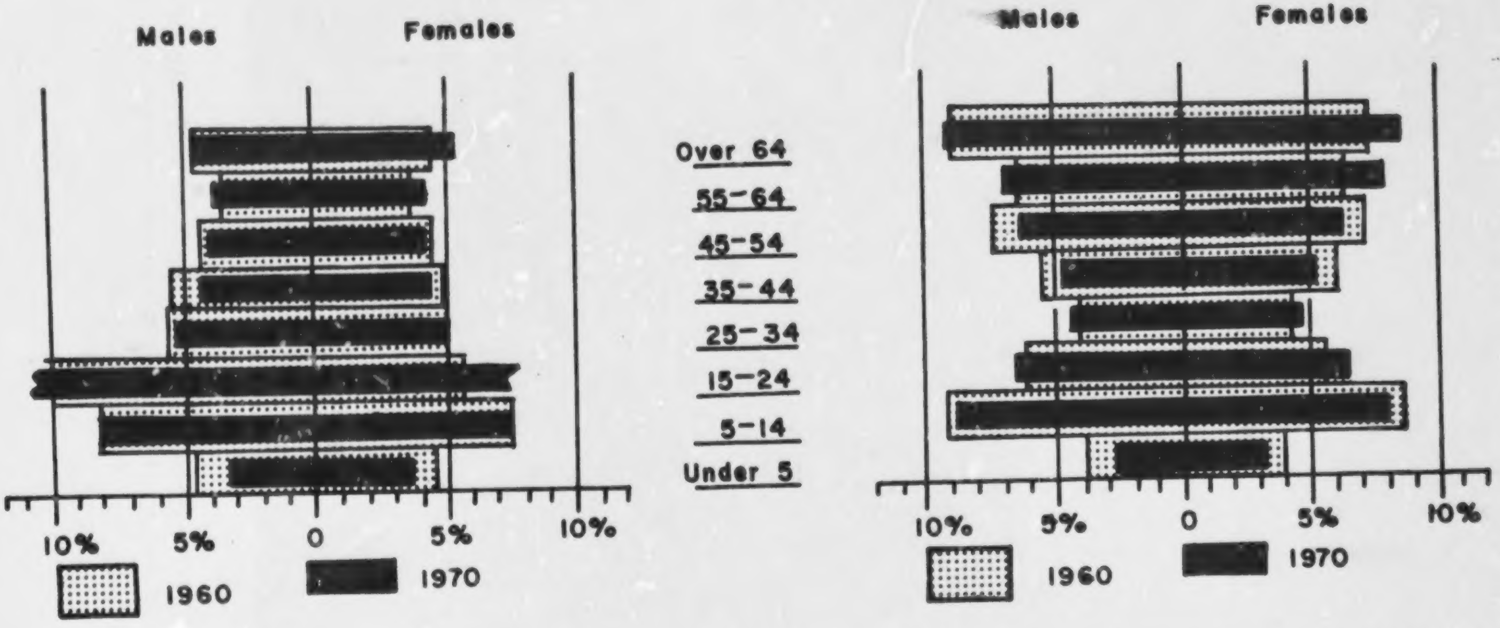
TABLE III-A

(continued)

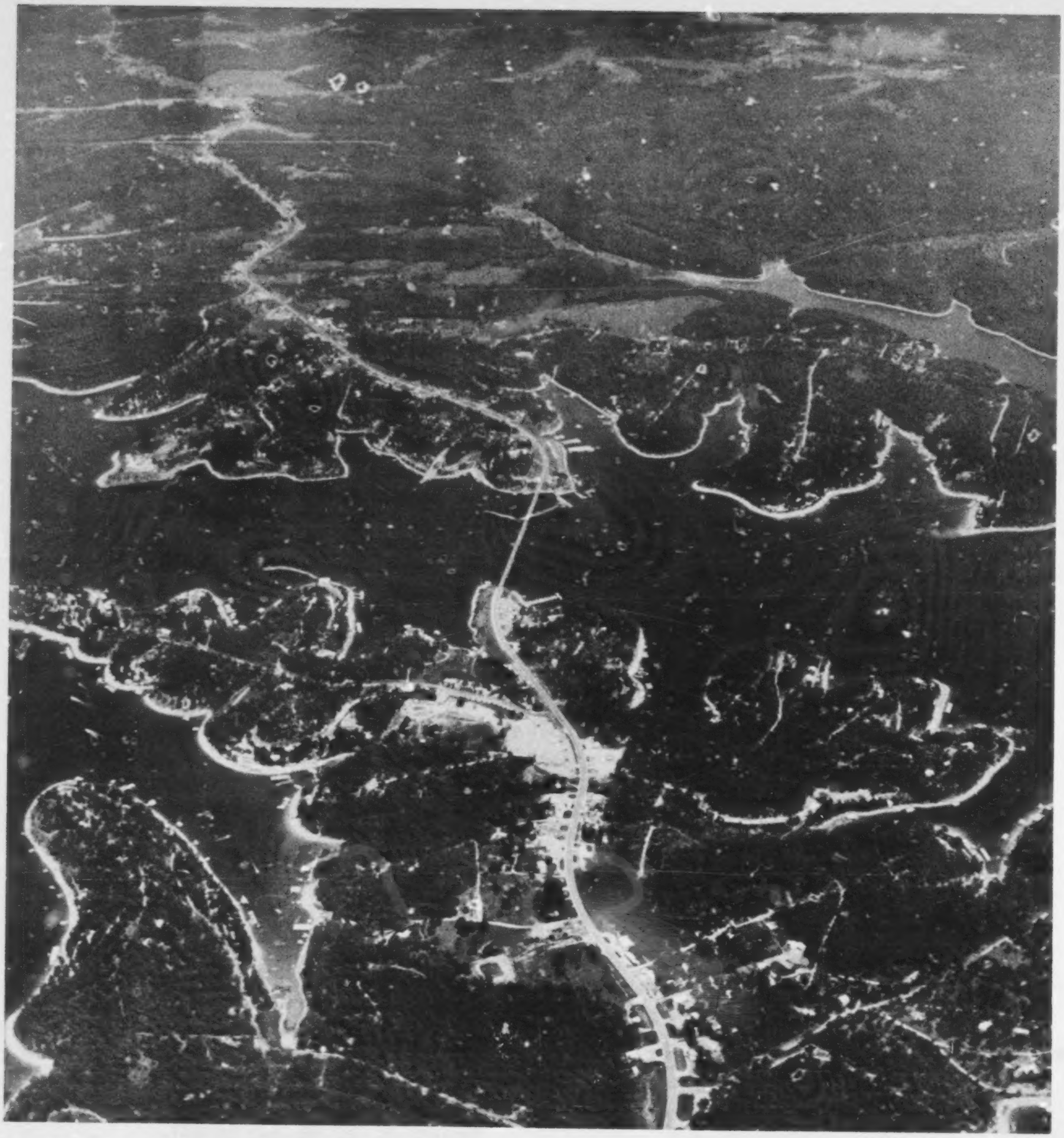
AGE GROUP

TRENDS 1960-1970
Lake of the Ozarks Region

TRENDS 1960-1970
Camden County



SOURCE : LAKE OF THE OZARKS REGIONAL PLANNING COMMISSION PRELIMINARY WATER & SEWER REPORT ((undated)



Aerial view of part of the Lake of the Ozarks showing scattered, ribbon development. (Photo by: Don Wooldridge, Missouri Department of Conservation)

The first is the age group of 65 and over. Each county in the Study Area has experienced an increase in this age group from 1960-1970, indicative of a growing retirement population. In the Lake area, this increase is 1.5 percent. The increase is particularly noticeable in the number of females. Such an older group is often unable to pay large amounts of taxes because of fixed retirement incomes, yet present a demand on tax dollars.

Two other age groups are 15-24 and 25-34 years of age. In all counties, findings are that young people remain in the region until about age 24. At this age, an out-migration occurs, mostly of males. This indicates males are probably leaving for better employment opportunities, as well as other economic and social advantages.

The fourth age group consists of persons under five years of age. In a healthy population pyramid, or one which has a great growth potential, the under five years group should be the largest. The unusually small percentage in each county is the direct result of the out-migration of persons in their peak childbearing years.

2. Components of Change. Counties around the Lake gained population from 1960 to 1970. However, this does not reveal the actual migration of people into and out of the counties. In the table below, the gain in population as a result of births is subtracted from the actual gain, to produce the amount of in (+) or out (-) migration.

TABLE III-B

Components of Change

1960-1970

	Actual Gain	Births	Deaths	Migration Amount	%
Camden	4,199	1,337	1,312	4,174	+45.7
Miller	1,226	2,503	1,731	454	+ 3.2
Morgan	592	1,306	1,380	666	+ 7.0
Benton	958	1,267	1,602	623	+ 7.1%

3. Population Projections.* Population projections were made for the years 1975, 1980, and 1990. No population loss is expected during

---

*Source: "Preliminary Water and Sewer Report"; Lake of the Ozarks Regional Planning Commission; Undated.

the planning period (1970-1990). According to historical trends, Morgan County will lose population. But at some point during the planning period this trend will be reversed, with Morgan County's population increasing. Camden County will experience considerable growth during this period.

The towns capable of furnishing services, such as water, sewer, and fire protection will experience the greatest growth. Those towns without these services will also show some growth, since many residents are unable or unwilling to pay for the services. The growth rate of such towns will be small and will be largely influenced by their location near major traffic routes.

LAND USE AND PLANNING

The most prevailing characteristic of the Study Area is that of timbered hills and valleys. Agricultural activity is confined generally to stream valleys, lands at the toe of hill masses and long hill ridges. A major change is occurring near the Lake where timbered lands have been and are being developed for large resorts, seasonal and yearly dwellings.

Enabling legislation which permits counties to plan and zone is found in Missouri Statutes, Sections 64.510-64.690. Little effort has been made to include planning and zoning as viable elements in county development--apparently, considerable resistance emerges when planning and/or zoning efforts are initiated. None of the counties around the Lake has adopted planning and/or zoning regulations.

GOVERNMENTAL UNITS

The incorporated communities in or near the Study Area are listed in Table III-C.

TABLE III-C
Incorporated Communities
Estimated 1973 Population
Lake of the Ozarks Region

Camdenton	1,636	Lakeside	124
Gravois Mills	34	Linn Creek	268
Hurricane Deck	169	Osage Beach	275
Lake Ozark	507	Sunrise Beach	126

Warsaw	1,423

Parts of Miller, Morgan, Camden and Benton County are in the Study Area.

The incorporated communities in the table do not have large populations. During the summer vacation season, however, the population in the Study Area approaches that of a larger metropolitan city. This influx is accommodated in areas outside the boundaries of an incorporated community. The combined capacity of the 485 motels in the Study Area greatly exceeds the size of the resident population. One of the most serious planning problems is the absence of a governmental unit to implement a plan encompassing more than one county.

CHAPTER IV

WATER QUALITY CONSIDERATIONS

GENERAL

The development of a comprehensive wastewater management system requires a thorough knowledge of the quality of the area's waters, the sources of pollution (present and projected), and the water quality objectives. Simply stated, a comprehensive wastewater management program for the Lake of the Ozarks Area must have two objectives:

1. Protection of the Lake of the Ozarks from further contamination and resulting eutrophication.

2. Enhancement of the quality of the Lake of the Ozarks and tributaries for optimum use.

It is significant that each objective includes both the public health and the aesthetic values inherent in successful environmental planning. In addition, a current discussion of water quality in the Lake of the Ozarks must consider the effects of the Harry S. Truman Dam, now under construction. An abstract of the Environmental Impact Statement required under PL 91-190 for the above project is included in this report and will be discussed in this chapter.

MISSOURI WATER QUALITY REQUIREMENTS

Under the Water Quality Act of 1965, all states, territories, and other affected jurisdictions were granted the option of preparing water quality standards for their interstate streams, rivers, lakes and coastal waters, or the possibility of the federal government doing it for them.

In accordance with this Act, the Missouri Clean Water Commission established and published water quality standards for all waters of the State. These standards, approved by the United States Environmental Protection Agency, are listed below:

WATER QUALITY STANDARDS

"Lake of the Ozarks

a. pH

The pH shall be between 6.5 and 8.5 in the Lake. A pH value above 8.5 shall not be due to waste discharges.

b. Dissolved Oxygen

The dissolved oxygen in the Lake shall not be less than 6 mg/l at any time due to effluents or surface runoff.

c. Temperature

The temperature of the water in the Lake shall not be increased due to any discharges which may be a source of heat.

d. Substances Potentially Toxic or Detrimental

Substances toxic to humans, fish and wildlife or detrimental to agricultural, mining, industrial, recreational, or other legitimate uses shall be limited to nontoxic or nondetrimental concentrations in the Lake.

e. Bacteria

The fecal coliform, in waters designated for whole body water contact recreation, shall not exceed a geometric mean of 200/100 ml, (either MPN or MF count) nor shall more than 10% of total samples during any 30-day period exceed 400/100 ml (either MPN or MF count). The above criteria shall not be applicable when the stream is affected by storm water runoff.

f. Taste and Odor Producing Substances

Taste and odor producing substances discharged shall be limited to concentrations in the Lake that will not impart unpalatable flavor to food fish, or result in noticeable offensive odors in the vicinity of the water, or otherwise interfere with legitimate use of the water.

g. Turbidity

There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of the Lake or interfere with its legitimate uses.

h. Color

There shall be no color of other than natural origin that will cause substantial visible contrast with the natural appearance of the Lake or interfere with its legitimate uses.

i. Oil and Grease

The Lake shall be virtually free of oil and grease.

j. Solids

> The Lake shall be free of floating debris, scum and other floating materials attributable to municipal, industrial or other waste disposal practices in amounts sufficient to be unsightly or deleterious. The Lake floor shall be free of materials which will adversely alter the composition of the bottom fauna, interfere with the spawning of fish o their eggs or adversely change the physical nature of the bottom."[2]

The Missouri Clean Water Law of 1972 requires the promulgation of effluent control regulations. Effluent regulations have been drafted and are being presented at public hearings throughout the state.

The Federal Clean Water Act of 1972 requires the establishment of effluent limitations for publicly owned treatment works in existence July 1, 1977 and those approved for construction grants before June 30, 1974. Secondary treatment is the minimum acceptable treatment for the above requirement. The Act states all publicly owned treatment works must employ the best practicable technology by 1983. The Act also requires that all point sources of wastewater have a permit to discharge to a navigable water. This permit will stipulate limits for pollutants in the discharge as well as other conditions for maintenance of water quality standards.

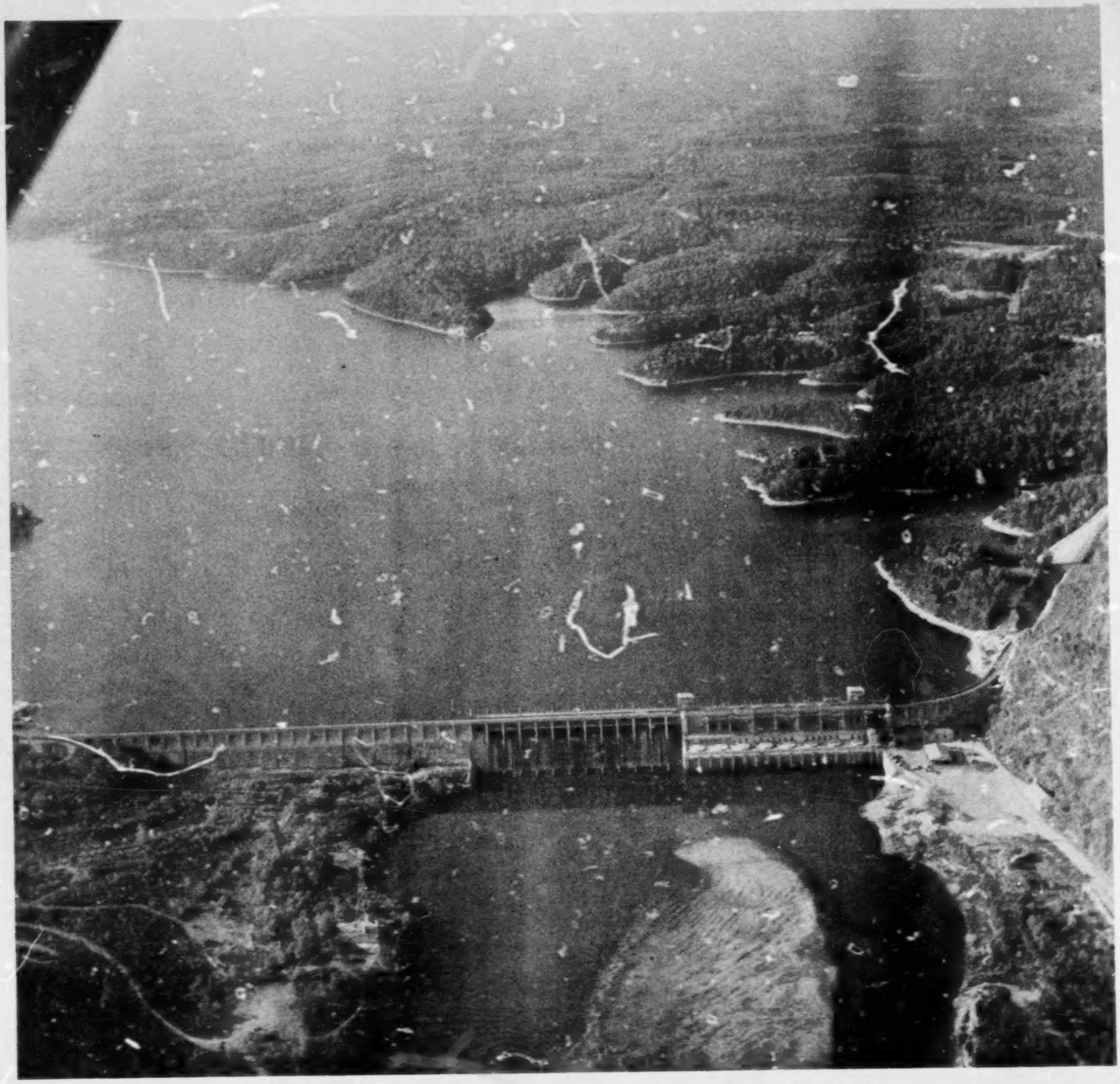
Implementation of the policies recommended in this study should ensure that the surface waters within the Study Area will meet the Water Quality Standards.

SPECIFIC CONSIDERATIONS
(POINT SOURCES)

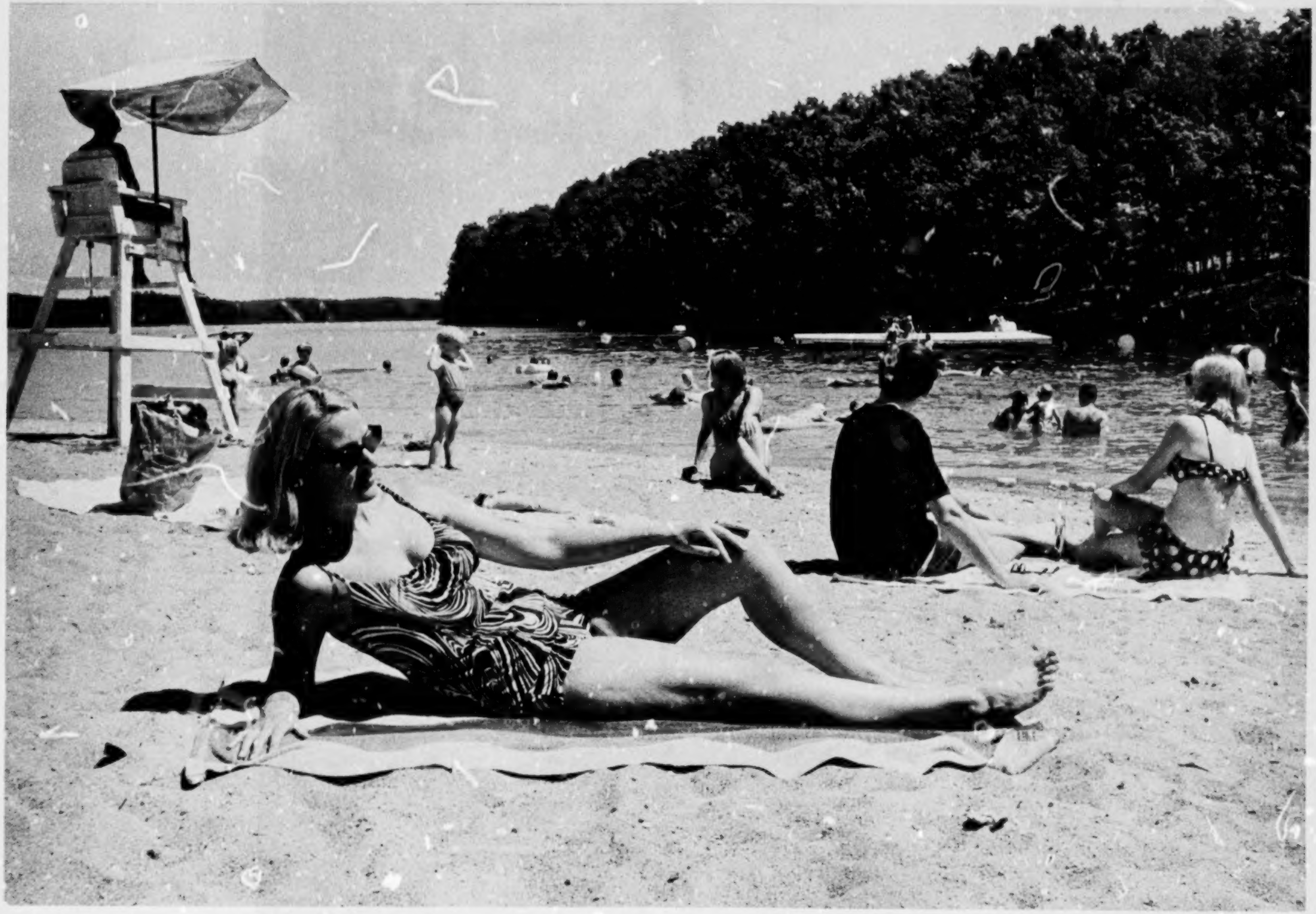
On August 6, 1929, the Union Electric Company initiated construction of Bagnell Dam, which formed the Lake of the Ozarks. Power generation started two years later, on October 16, 1931. The one-half mile long dam on the Osage River impounds 2,100,000 acre-feet of water and covers an area of 93,000 square miles at full pool. The dam is 172 miles from St. Louis, 150 miles from Kansas City, and 42 miles from Missouri's capital, Jefferson City.

From September 1970 to October 1971, the U.S. Environmental Protection Agency conducted water quality investigations of the Lake of the Ozarks. The purpose was to provide technical information for the development of this management plan. Studies were conducted to:

1. Document the present physical, chemical and biological quality of the Lake of the Ozarks;



Overview of Bagnell Dam.



Swimming beach on the Lake of the Ozarks. (Photo by Walker, Missouri Tourism Commission)

2. Evaluate existing waste treatment facilities discharging into the Lake or its tributaries;

3. Develop a comparison of selected water quality parameters during the spring and summer seasons.

Information for these objectives was selected by monitoring on a monthly frequency and through short period intensive surveys. The monthly sampling occurred at 21 stations from September 1970 to October 1971, and intensive surveys were conducted during May and July of 1971.

Currently, four distinct sources of pollutants reaching the Lake are: tributary streams which carry wastes discharged by communities and overland runoff from precipitation; treated wastes discharged directly into the Lake by communities and resorts; leachate from septic tanks serving residences and resorts on the Lake shore; and direct waste discharge from boats and marinas.

The two largest municipal discharges affecting the Lake of the Ozarks are Camdenton (population approximately 1,600), and Warsaw (population approximately 1,200). Camdenton's treatment facilities consist of seven widely scattered lagoons. All of these facilities eventually discharge into the Lake.

At one time, Warsaw was served by a form of community septic tank. This was followed by a lagoon discharging into the Osage River. Construction of a new system of lagoons and abandonment of the septic tank in Warsaw is now underway. Data from composite samples out of the South Camdenton Lagoon which discharged into Minow Creek, and from the existing Warsaw Lagoon, are shown in Table IV-A.

Camdenton's data for May reflect a very weak waste. No overflow occurred in July, and no data are shown. The data for Warsaw reflect a better degree of treatment in May than July. Both systems contribute some nutrients to the Lake drainage. The nutrient levels will be discussed later in this study.

Wastes discharged by the resorts were typified by the measurements of the effluent waste treatment facilities at Holiday Inn. The Holiday Inn is employing three extended aeration plants for treatment of its wastes. During May, 1971, one plant achieved 70 percent nonfilterable solids reduction and 80 percent BOD reduction. Another of the three plants achieved 42 percent nonfilterable solids reduction and 83 percent BOD_5 reduction. During this effort, both plants were operating below possible efficiencies.

During July, Holiday Inn Plants were considered as one plant because of the relatively low flows. The plants at that time achieved 90 percent BOD_5 reduction, and appeared to be functioning properly. The data from the Holiday Inn Study are shown in Table IV-B.

TABLE IV-A

WASTE TREATMENT LAGOON ANALYSES
CAMDENTON AND WARSAW MISSOURI
MAY AND JULY 1971

(VALUES IN MG/L)

CAMDENTON COMPOSITE SAMPLE
May 27, 1971

	Nonfilt Solids	NH_3 N	Org N	NO_3-NO_2 N	Ortho P	Total P	COD	BOD_5
Upstream	--	0.05	0.15	0.47	0.00+	0.03	3	1.4
Influent	55	11	4	0.20	2.00	2.70	92	54
Effluent	67	0.65	7.4	0.11	0.38	1.20	124	28
Downstream	--	0.54	0.47	*	0.06	0.09	19	3.0

* No Result

NO JULY SAMPLE FOR CAMDENTON BECAUSE OF NO DISCHARGE

WARSAW COMPOSITE SAMPLE
May 26, 1971

	Nonfilt Solids	NH_3 N	Org N	NO_3-NO_2 N	Ortho P	Total P	COD	BOD_5
Upstream	--	0.17	1.55	0.51	--	--	10	4.1
Influent	116	23	14	0.03	13	13	317	154
Effluent	210	1.15	5.0	0.09	.39	.51	110	30
Downstream	--	0.35	.55	0.53	.03	.07	41	3.8

WARSAW COMPOSITE SAMPLE
July 26, 1971

	COD	BOD_5
Upstream	12	2.7
Influent	236	164
Effluent	94	15
Downstream	10	2.2

TABLE IV-B

HOLIDAY SEWAGE TREATMENT PLANT
OPERATION DATA FOR MAY AND JULY 1971

(VALUES IN MG/L)

HOLIDAY INN NORTH PLANT

MAY 28, 1971

COMPOSITE SAMPLE DATA

0600 to 1200	Nonfilt Solids	NH_3 N	Org N	NO_3-NO_2 N	Ortho P	Total P	COD	BOD_5
Influent	72	5.5	42	0.36	4.90	7.50	125	106
Effluent	22	0.14	1.54	14.0	4.95	7.30	19	22

HOLIDAY INN SOUTH PLANT

MAY 28, 1971

COMPOSITE SAMPLE DATA

0600 to 1200	Nonfilt Solids	NH_3 N	Org N	NO_3-NO_2 N	Ortho P	Total P	COD	BOD_5
Influent	90	6.9	19	0.02	9.13	9.30	391	274
Effluent	52	2.3	4.6	0.69	3.90	4.90	136	47

HOLIDAY INN - NORTH AND SOUTH PLANT COMBINED

JULY 28, 1971

COMPOSITE SAMPLE DATA

0600 to 1200	COD	BOD_5
Influent	340	153
Effluent	89	16

None of the sampling stations surveyed showed any direct changes in water quality due to septic tank leachate. This indicates no measurable changes occurred during the times and at the location where samples were taken. The available data on this problem are insufficient to draw any major conclusions for the Lake of the Ozarks. Further studies must be undertaken because of the serious effects of any potential problem.

Wastes from vessels and marinas are subject to control through existing state legislation and federal regulations. State laws require holding tanks and prohibit discharge of wastes from vessels, except at approved shore pumpout stations. The wastes near marinas can be controlled through better employee training, better housekeeping, and stronger enforcement of existing anti-litter laws. Nearly all of the polluting material entering the water at marinas is due to carelessness.

The last phase of the investigation was a study of primary production in the Lake. Two coves were selected to provide a comparison between productivity rates and degree of shoreline development. One cove was subject to high use; the other had very little or no formal use.

The depth of the euphotic zone (the area receiving one percent or more of surface illumination) was measured daily with a submarine photometer. Temperature profiles were obtained using a thermistor capable of measuring forty feet depths. All values presented in the tables and figures, unless otherwise noted, are calculated averages for the four stations at each cove.

During May, 1971, the two study coves did not have definable thermoclines (Figure IV-C). Water temperatures ranged from 15° C at the surface to 12° C at the 35 feet depth. Dissolved oxygen concentrations from surface to the 40 feet depth ranged from 11.40 milligrams per liter to 7.20 mg/l, respectively. Previous studies indicated the reservoir becomes thermally stratified during the latter part of May and remains stratified through October. Figure IV-D illustrates the dissolved oxygen and temperature profiles for July which indicate stratification was occurring.

The phytoplankton collected during the May survey were primarily centric diatoms. Table IV-E lists the types and relative abundance of phytoplankton during both sampling periods. The diatoms Melosira and Cyclotella which were the predominate genera during the spring months are common during spring blooms in bodies of water classified as "mesotrophic" (moderately enriched). The July sampling period revealed that the coccoid green algal forms were predominate in the collections, but few in number (<1,500/milliliters). Reservoirs which are mesotrophic generally have phytoplankton standing crops of 5,000 cells/ml or more during the summer months.

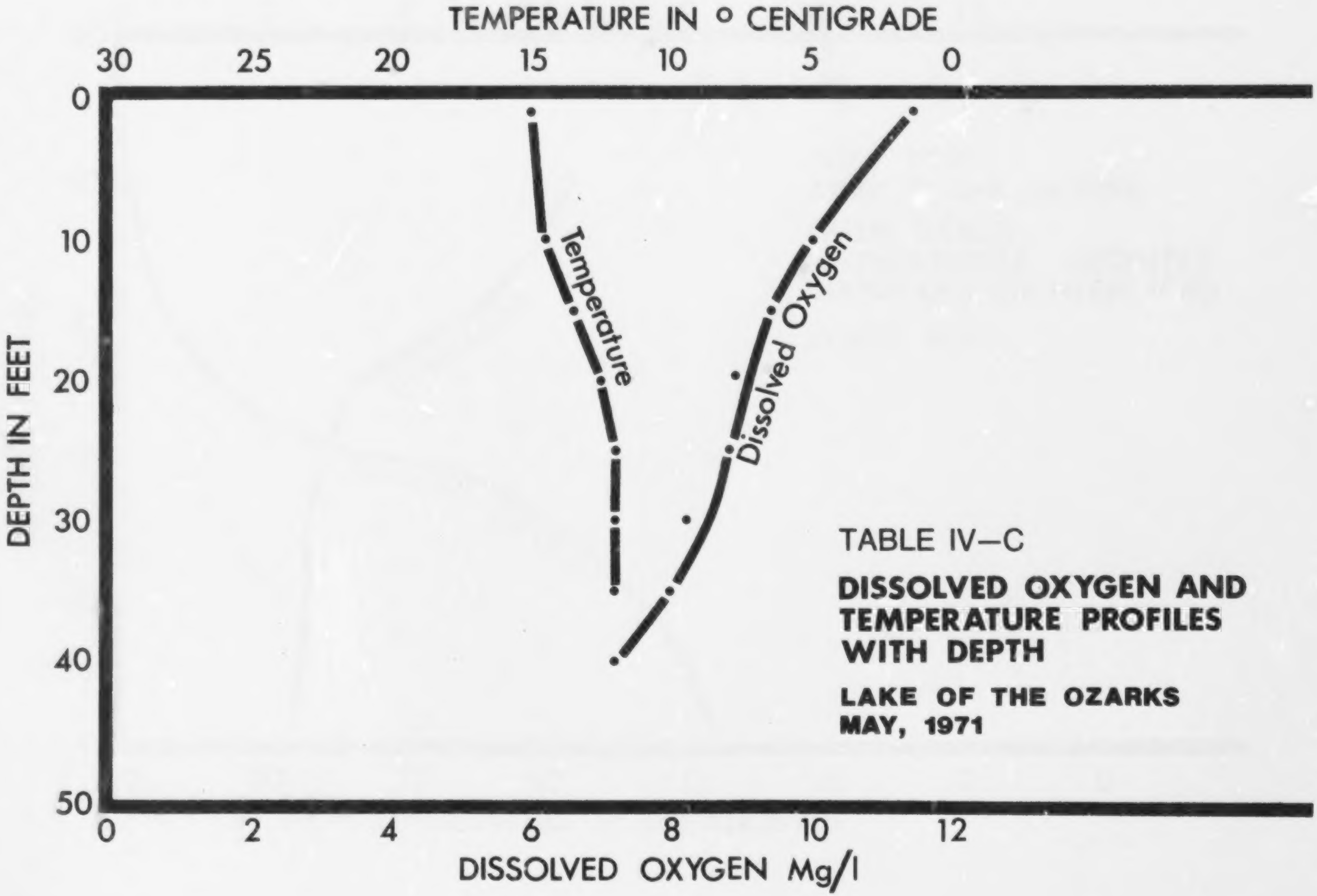


TABLE IV—C

DISSOLVED OXYGEN AND TEMPERATURE PROFILES WITH DEPTH

LAKE OF THE OZARKS
MAY, 1971

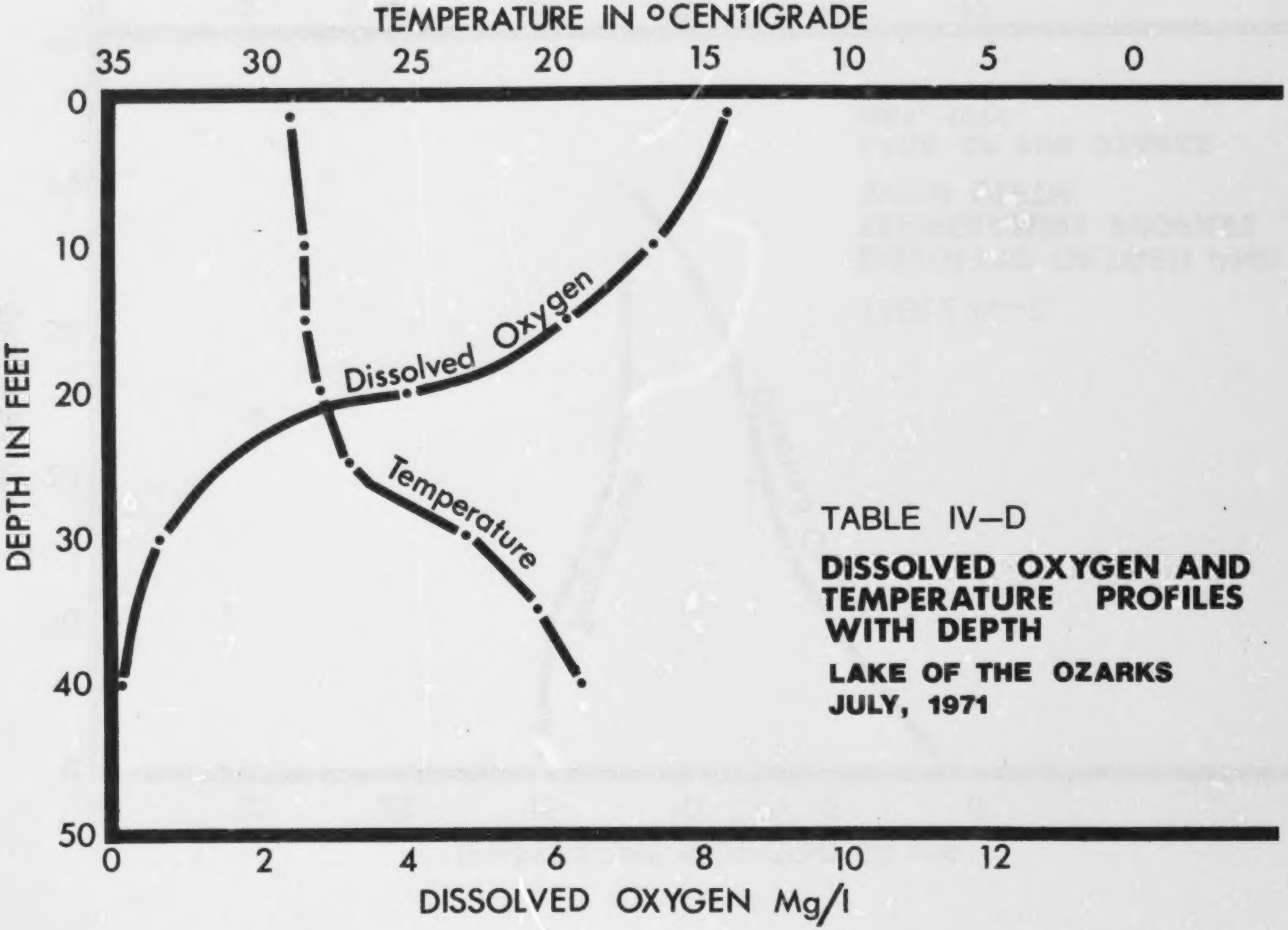


TABLE IV—D

DISSOLVED OXYGEN AND TEMPERATURE PROFILES WITH DEPTH

LAKE OF THE OZARKS
JULY, 1971

TABLE IV-E

SUMMARY OF PHYTOPLANKTON COUNTS
WITH THE FOUR MOST ABUNDANT GENERA
LAKE OF THE OZARKS
MAY AND JULY 1971

May 1971

Heavy-Use Cove		Low-Use Cove	
Genera	No./ml	Genera	No./ml
Melosira	385	Melosira	365
Cyclotella	338	Cyclotella	356
Synedra	228	Synedra	261
Asterionella	66	Asterionella	132
Total Number	1,128	Total Number	1,298

July 1971

Heavy-Use Cove		Low-Use Cove	
Genera	No./ml	Genera	No./ml
Chlamydomonas	495	Chlorella	274
Kirchneriella	297	Scenedesmus	165
Chlorella	99	Chlamydomonas	165
Scenedesmus	33	Crucigenia	66
Total Number	2,221	Total Number	2,574

Chemical analysis during both sampling periods revealed major algal growth nutrients, nitrogen and phosphorus, near or below levels required for algal blooms (Tables IV-F and IV-G). Surface waters from both coves had concentrations of inorganic nitrogen ranging from 0.50 to 0.85 mg/l, with soluble phosphorus levels from nondetectable amounts to 0.01 mg/l. Data from surveys of 17 known eutrophic lakes in Wisconsin revealed concentrations of 0.01 mg/l of soluble phosphorus and 0.30 mg/l of inorganic nitrogen during spring overturn could stimulate algal blooms.

If conditions in the selective study coves are representative of the entire Lake, it is apparent from reported macronutrient concentrations that soluble phosphorus is probably one of the limiting factors governing excessive algal growths in the Lake of the Ozarks.

The rate of primary production is an index which may be used to classify waters and to provide a relative estimate of phytoplankton populations and available nutrients. This measurement is defined as the rate of photosynthetic carbon fixation by plants (algae) and bacteria forming the base of the food chain.

Figures IV-H and IV-I illustrate the rate of primary production expressed as milligrams of carbon fixed per cubic meter per day ($MgC/M^3/$day) for both coves. The May period had the greatest rate of production occurring in the first few feet of the water column. The euphotic zone extended to the twenty-feet depth, but the low volumetric values below the ten-feet depth indicate the scarcity of phytoplankton. The gross primary productivity during the May period ranged from 591 to 817 MgC/M^2/day for the heavy and low-use coves, respectively.

Primary productivity rates increased at both coves in July, most notably at the heavy use cove. The low-use cove rates increased slightly over the May values, compared with the heavy-use cove where carbon fixation rates doubled (Figures IV-H and IV-I).

Compared with other lakes of similar size and age, the Lake of the Ozarks is relatively unproductive in terms of phytoplankton standing crops and primary production.

The heavy-use cove, compared with the low-use cove, was the most productive in terms of carbon fixation. Chemical analyses of surface waters from this cove failed to detect levels of nutrients which could originate from inadequate sewage disposal. During both survey periods, the essential growth nutrients, nitrogen and phosphorus, were insufficient in quantity to stimulate and sustain blooms of phytoplankton, thus restricting primary production.

Fecal coliform data collected indicate significant densities for one Lake station and for several tributaries. These levels are attributable to samples collected during high water periods. At normal flow conditions, the observed densities were below levels established for whole body contact recreation, i.e., 200 organisms per 100 ml.

TABLE IV-F

SUMMARY OF CHEMICAL AND BIOLOGICAL FINDINGS
LOW-USE COVE - LAKE OF THE OZARKS
MAY AND JULY 1971

	May 1971	July 1971
Gross Primary Production MgC/M^2/day	817.00	955.75
Depth of Euphotic Zone Feet	20	15
Phytoplankton No. Algae Cells/ml (1)	1,298	2,574
Total Phosphorus Total-P mg/l (1)	0.01	0.02
Soluble Phosphorus Ortho-P mg/l (1)	Not Detectable	0.01
Inorganic Nitrogen NO_2-NO_3-N mg/l (1)	0.85	0.09
Organic Nitrogen Org-N (1)	0.60	0.29

(1) Values For Surface Collections

TABLE IV-G

SUMMARY OF CHEMICAL AND BIOLOGICAL FINDINGS
HEAVY-USE COVE - LAKE OF THE OZARKS
MAY AND JULY 1971

	May 1971	July 1971
Gross Primary Production MgC/M^2/day	591.25	1,107.33
Depth of Euphotic Zone Feet	20	15
Phytoplankton No. Algae Cells/ml (1)	1,128	2,221
Total Phosphorus Total-P mg/l (1)	0.04 (2)	0.02
Soluble Phosphorus Ortho-P mg/l (1)	Not Detectable (2)	0.01
Inorganic Nitrogen NO_2-NO_3-N mg/l (1)	0.50 (2)	0.18
Organic Nitrogen Org-N mg/l (1)	0.44 (2)	0.36

(1) Values For Surface Collections

(2) Values Taken From Sampling Station In Main Body Of Lake Outside Of Cove

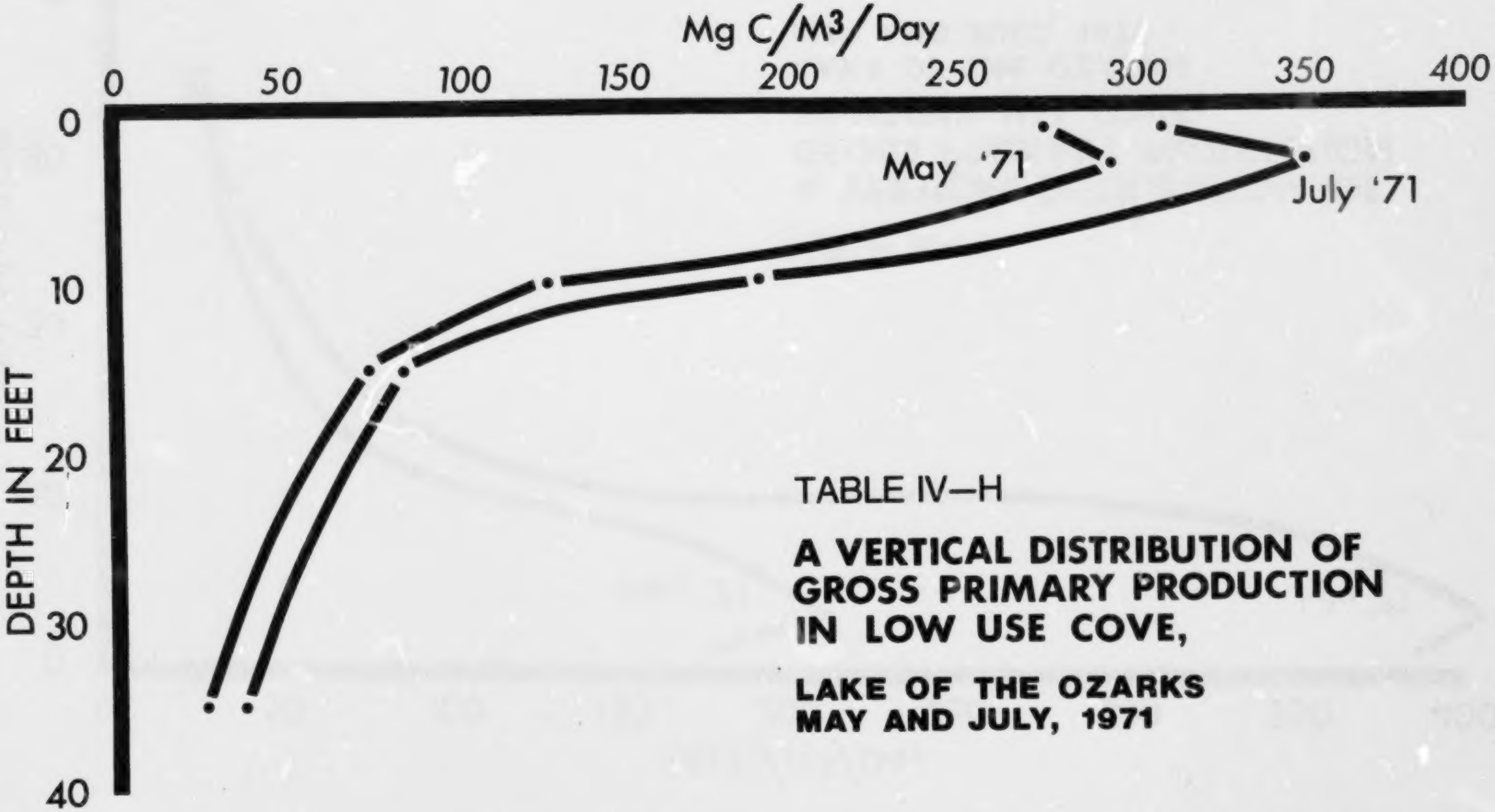


TABLE IV—H

A VERTICAL DISTRIBUTION OF GROSS PRIMARY PRODUCTION IN LOW USE COVE,

LAKE OF THE OZARKS
MAY AND JULY, 1971

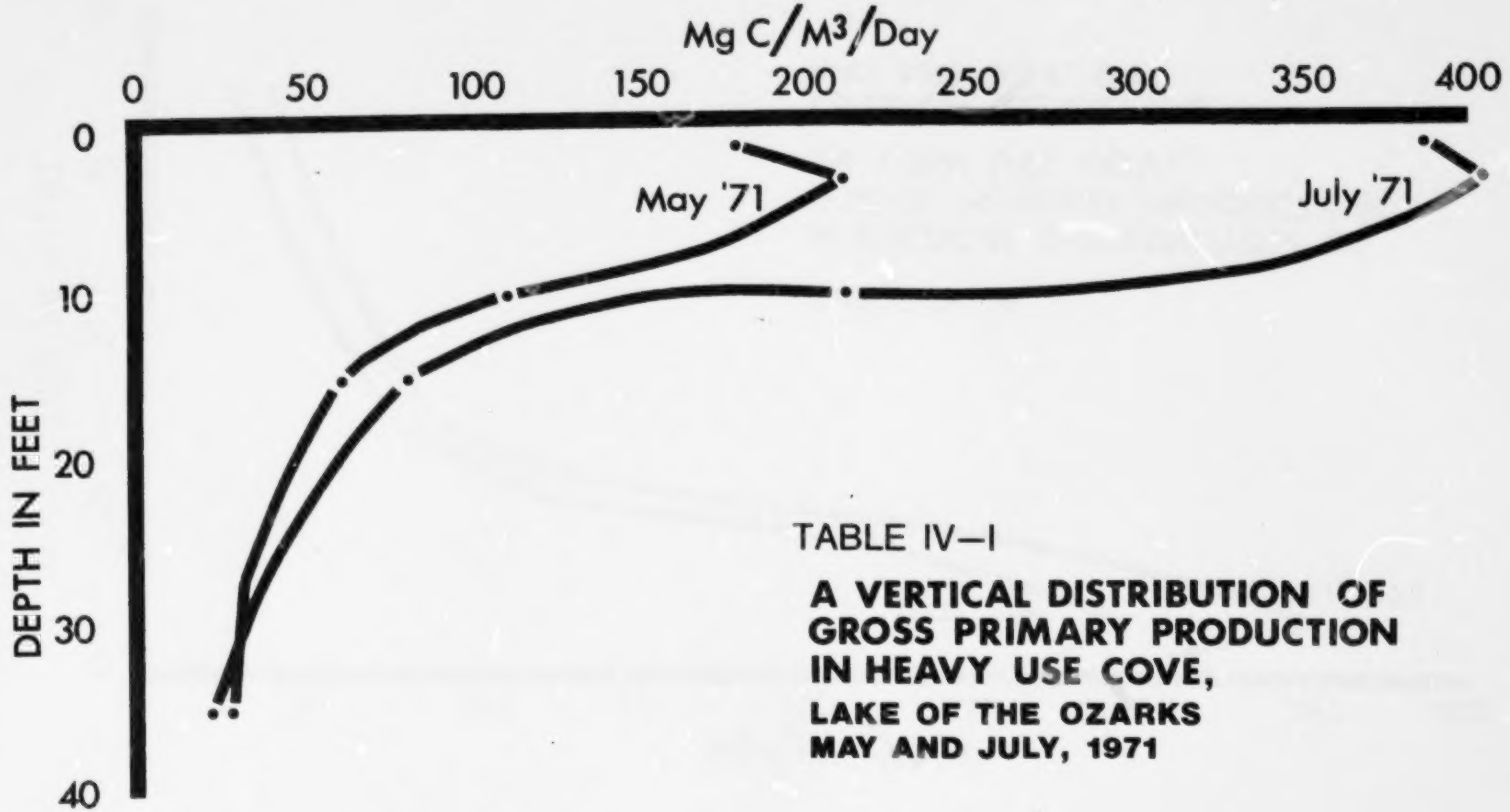


TABLE IV—I

A VERTICAL DISTRIBUTION OF GROSS PRIMARY PRODUCTION IN HEAVY USE COVE,
LAKE OF THE OZARKS
MAY AND JULY, 1971

Results of intensive bacteriological studies in May and July of 1971 are shown in Tables IV-J and IV-K. The data in these tables are arithmetic means of five to seven analyses. Figure IV-L is a graphical representation of all of the data and presents significant trends.

The bacterial densities in the cove surrounded by residences show little difference between May and July. The seasonal numerical difference shown by the plot for Millstone Cove is somewhat higher, reflecting the heavier summer use. The Holiday Inn Cove, which receives the effluent from the Inn Sewage Treatment Plant, shows the greatest increase in bacterial densities.

SPECIFIC CONSIDERATIONS
(NON-POINT SOURCES)

To evaluate the impact of agricultural activities on the water quality of the Lake of the Ozarks, agricultural data on the drainage basin were reviewed, and consultations held with agricultural extension service personnel in the Study Area. This study surveyed areas which drain into the Lake between Bagnell Dam and Warsaw. All or part of nine counties are contained within the basin as defined above (see Table IV-M). However, five counties--Benton, Camden, Dallas, Laclede and Morgan--contribute 90 percent of the land area to the basin. Since the other four counties do not contribute significantly to the basin, the following discussion includes only the five counties.

The land use data for the basin in Table IV-N was taken from county based data in the 1970 Missouri Conservation Needs Inventory. The assumption was made that the land use was uniformly distributed throughout the region. This assumption is somewhat inaccurate, but it provides some indication of land use in the basin.

The general geology of the basin is characterized as a highly dissected old mountain range with narrow, gently rolling divides and steep, stony side slopes. The bedrock is predominantly dolomite, cherty dolomite and sandstone of Ordovician Age. Stream valleys are predominantly narrow and are subject to high intensity rainstorms which result in severe flash floods. (See Figure IV, Generalized Geologic Map of the South Grand-Osage River Basin.)

The soils developed under timber vegetation are mostly light colored, shallow and stony. The gently rolling to hilly, cherty uplands and associated stream bottoms have reddish-brown and yellowish-brown soils which are moderately well drained and contain small amounts of chert in the surface, increasing with depth. Primarily steep, rough, stony areas with associated narrow ridges and narrow stream valleys have soils with high chert content. The major problems with these soils are limited land use adaptability and potential for

TABLE IV-J

Summary of Observed Fecal Coliform Densities in a Cove Surrounded by Residential Development

Lake of the Ozarks

May and July 1971

STATION		MEAN 1/ COLIFORM DENSITY MF/100ML	
		MAY	JULY
LO 101	Main Lake Channel at Mouth of Study Cove	2	2
LO 102	Mouth of Study Cove	6	2
LO 103	1,000 Feet from Mouth Center Line of Study Cove	17	100 2/
LO 104	2,500 Feet from Mouth Center Line of Study Cove	6	2
LO 105	4,000 Feet from Mouth Center Line of Study Cove	8	5
LO 106	Open Water - Study Cove SE Corner	6	2
LO 107	Near Shore SE Corner	11	5
LO 108	Open Water - NW Corner	19	3
LO 109	Open Water - NW Corner	13	5
LO 110	Open Water - NW Corner	12	6
LO 111	Near Shore North End	15	12
LO 112	Near Shore NE Corner	5	4
LO 113	Near Shore NE Corner	3	7
LO 114	Open Water Southeast	3	3
LO 115	Near Shore SE Corner	NS 3/	2

1/ Arithmetic means based on five observations from samples collected before noon

2/ One value of 480 organisms per 100 ml all others less than 10

3/ Not sampled in May

TABLE IV-K

Summary of Fecal Coliform Data in Two
Lake of the Ozark Coves with Resort Marinas

May and July 1971

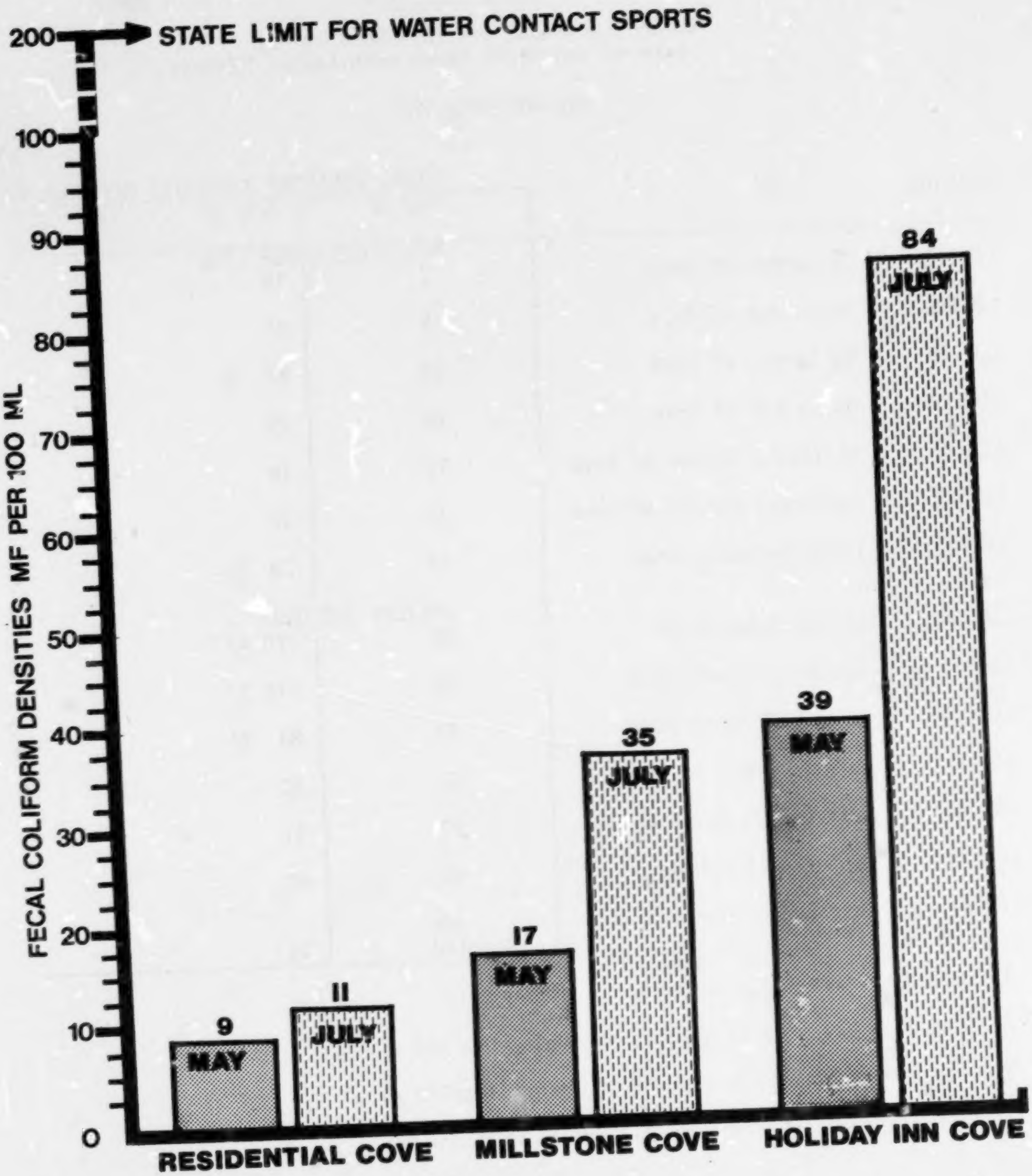
STATION		FECAL COLIFORM DENSITIES MF/100ml	
		May 1/	July 2/
		MILLSTONE LODGE COVE	
LO 117	SW Corner of Cove	7	18
LO 118	West Edge of Cove	9	25
LO 119	NW Corner of Cove	25	52 3/
LO 120	North End of Cove	25	28
LO 121	Northeast Corner of Cove	12	10
LO 122	Southeast Corner of Cove	27	32
LO 123	Lodge Swimming Area	13	78 3/
		HOLIDAY INN COVE	
LO 124	SE End South Cove	28	170 4/
LO 125	Center of South Cove	35	110 3/
LO 126	NE end of South Cove	37	88 3/
LO 127	Lake in Front of Inn	62	50
LO 128	West end of North Cove	27	61
LO 129	Center of North Cove	42	51
LO 130	East End of North Cove	Not Sampled	55

1/ Based on five daily samples

2/ Based on seven daily samples including weekend

3/ One observation in excess of 200 organisms/100 ml

4/ Three values in excess of 200 organisms/100ml



FECAL COLIFORM DENSITIES

TABLE IV—L

Lake Of The Ozarks
May and July 1971

TABLE IV-M LAKE OF THE OZARKS DRAINAGE

Basin - Area Breakdown by Counties

	Total Land Area in County[1] (sq. mi.)	Area of County in Drainage Basin (sq. mi.)	% of County Within Drainage Basin	% of Drainage Basin
Benton[2]	743	350	47	16
Camden[2,3]	655	610	100	28
Dallas[2]	536	480	90	22
Hickory	400	87	20	4
Laclede[3]	770	262	34	12
Miller[3]	603	44	7	2
Morgan[2,3]	595	240	40	11
Pulaski[3]	551	22	4	1
Webster	590	87	15	4

[1] From 1970 Missouri Conservation Needs Inventory

[2] Significant part of county contributing to the Lake of the Ozarks Basin

[3] Member of the Lake of the Ozarks Planning Commission

TABLE IV-N OZARK BASIN LAND USE[1]

	Land Use By Acres	Land Use By % of Total Land Area	% of Each Categories Needing Conservation Treatment
Corn and Sorghum	36,600	2.9	-----
All other Row Crops	4,100	.3	-----
Close Grown Field Crops	18,260	1.4	-----
Rotation Hay and Pasture	71,900	5.7	-----
Hayland	20,880	1.6	-----
Conservation Use Only	33,100	2.6	-----
Temporarily idle Cropland	6,100	.5	-----
Orchard Vineyard and Bush Fruit	200	---	-----
Open Land Formerly Cropped	1,605	.1	-----
TOTAL CROPLAND	192,745	15.2	48.2
Pasture	209,400	16.5	84.0
Range	27,860	2.2	59.2
TOTAL PASTURE & RANGE	237,260	18.7	-----
Forest Land Commercial	679,900	53.5	92.6
Forest Land Non-Commercial	39,024	3.0	17.2
TOTAL FOREST LAND	718,924	56.5	-----
Other Land in Farms	18,080	1.4	-----
Other Land Not in Farms	10,250	.8	-----
TOTAL OTHER LAND	28,330	2.2	-----
Federal Land	19,362	1.5	-----
Urban and Built-up Areas	68,370	5.4	-----
Water Areas Greater Than 2 and Less Than 40 Acres	6,120	.5	-----
TOTAL NON-INVENTORY ACREAGE	93,852	7.4	-----
TOTAL BASIN	1,271,111	100.00	

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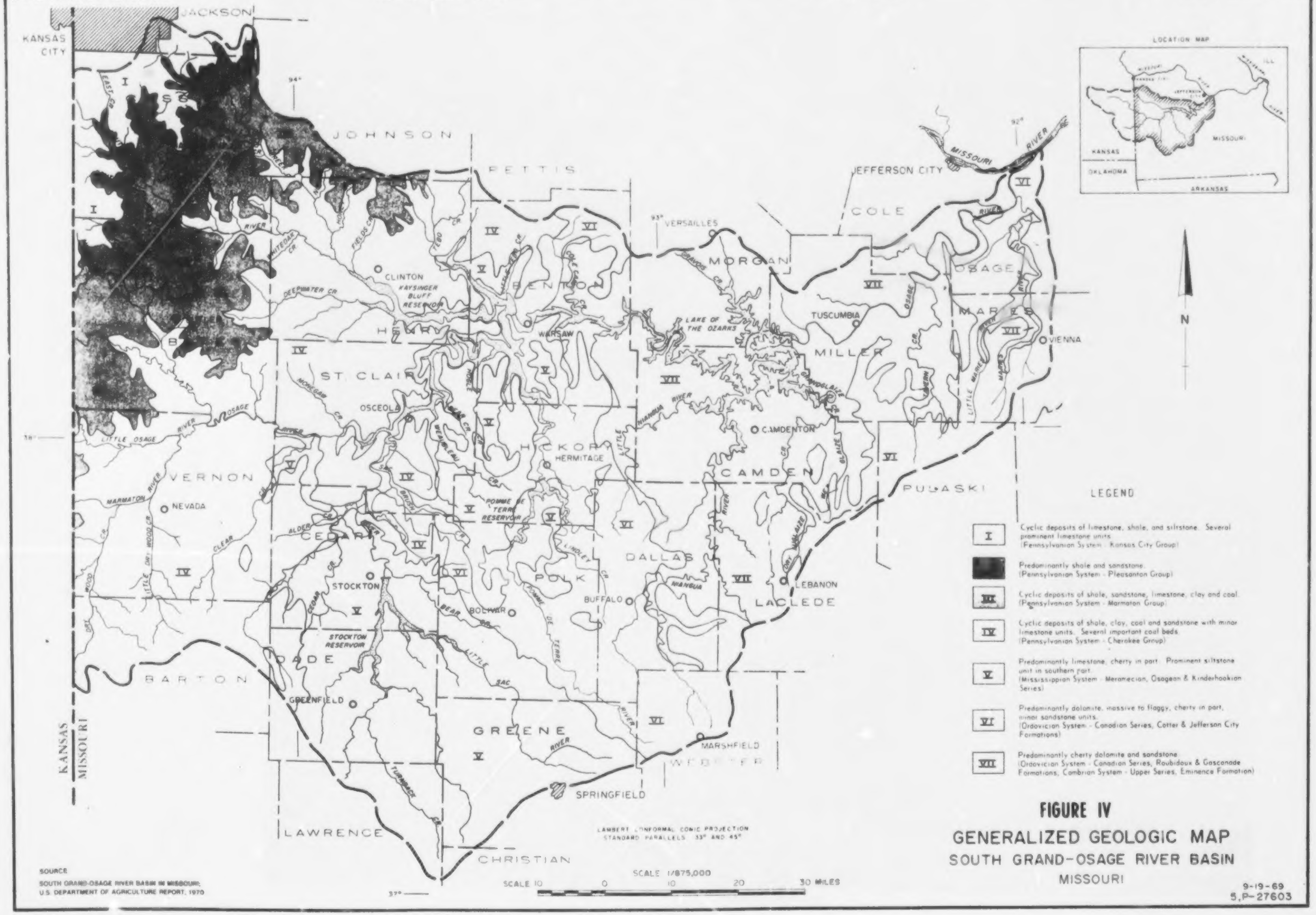
[1] Data Prorated to basin from data in 1970 Missouri Conservation Needs Inventory

U.S. DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE FOREST SERVICE SOIL CONSERVATION SERVICE



LEGEND

I	Cyclic deposits of limestone, shale, and siltstone. Several prominent limestone units. (Pennsylvanian System - Kansas City Group)
■	Predominantly shale and sandstone. (Pennsylvanian System - Pleasanton Group)
III	Cyclic deposits of shale, sandstone, limestone, clay and coal. (Pennsylvanian System - Marmaton Group)
IV	Cyclic deposits of shale, clay, coal and sandstone with minor limestone units. Several important coal beds. (Pennsylvanian System - Cherokee Group)
V	Predominantly limestone, cherty in part. Prominent siltstone unit in southern part. (Mississippian System - Meramecian, Osagean & Kinderhookian Series)
VI	Predominantly dolomite, massive to flaggy, cherty in part, minor sandstone units. (Ordovician System - Canadian Series, Cotter & Jefferson City Formations)
VII	Predominantly cherty dolomite and sandstone. (Ordovician System - Canadian Series, Roubidoux & Gasconade Formations, Cambrian System - Upper Series, Eminence Formation)

LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS 33° AND 45°

SCALE 1/875,000
SCALE 10 0 10 20 30 MILES

FIGURE IV

GENERALIZED GEOLOGIC MAP
SOUTH GRAND-OSAGE RIVER BASIN
MISSOURI

SOURCE
SOUTH GRAND-OSAGE RIVER BASIN IN MISSOURI;
U.S. DEPARTMENT OF AGRICULTURE REPORT, 1970

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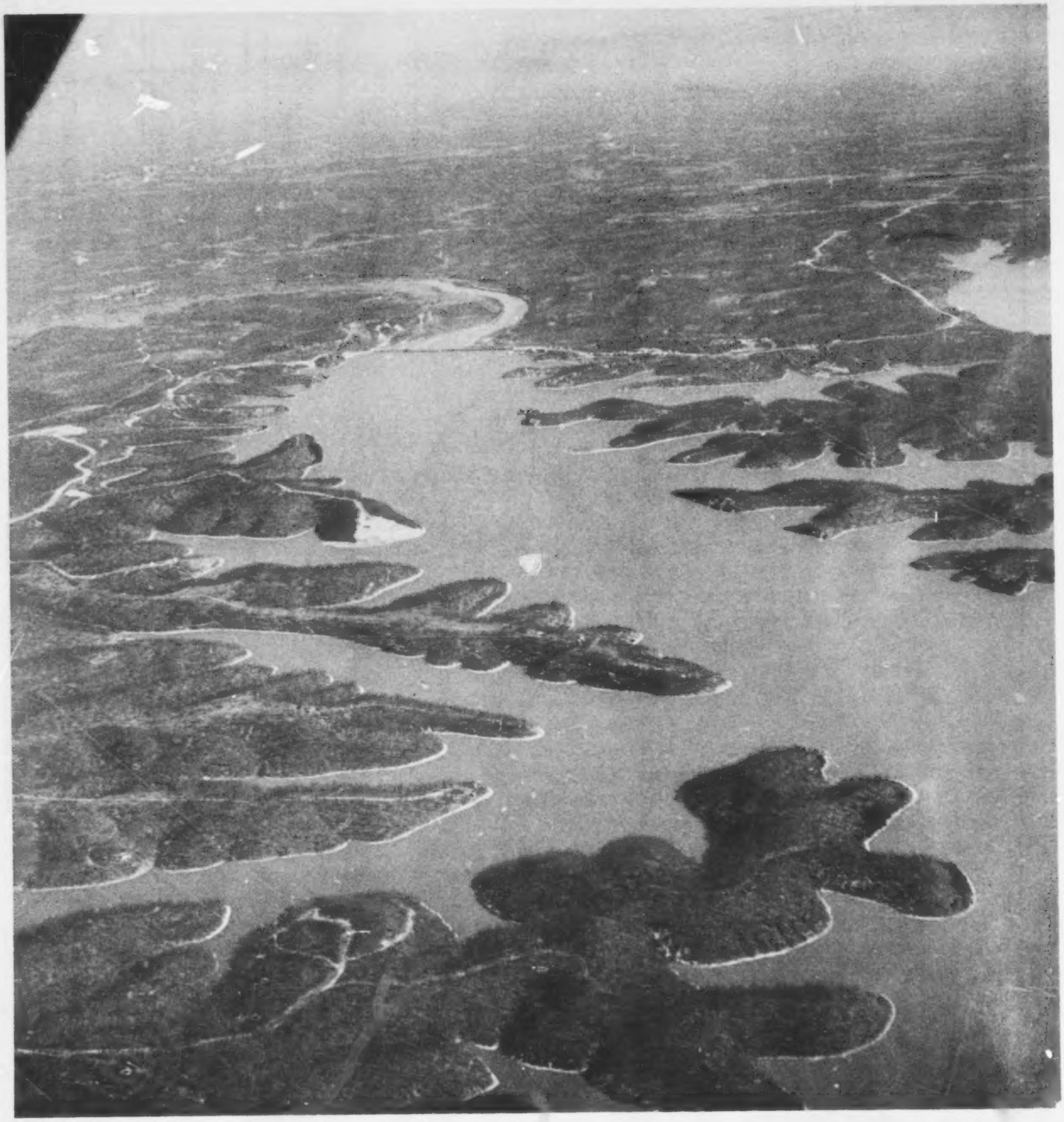

Aerial view of the Lake of the Ozarks. Note Bagnell Dam in upper third of photograph and the extremely long shoreline. (Photo by: Don Wooldridge, Missouri Conservation Commission) erosion. The climatic pattern of alternate drought and flooding determines land use. (See Figure V, Generalized Soils Map, South Grand-Osage River Basin.)

The normal annual precipitation for the basin is 39 to 42 inches, but the annual variations are very great. The average annual runoff is ten to eleven inches. Compared with other areas of more intensive agriculture and deeper soils, the annual sediment yield is low. An average of 0-100 tons/mi^2/year or 0-.156 tons/acre/year of soil are eroded. Most of the damage is from sheet and rill erosion.

AGRICULTURAL PATTERNS

Agricultural activities are limited by the geology, topography and soil conditions in the basin. The rocky soils are not well suited for cropping. Only 3.2 percent of the land is devoted to row crops (see Table IV-N), and total cropland covers only 15.2 percent of the land area. The Conservation Needs Inventory indicates 48.2 percent of the total cropland in tillage rotation needs some conservation treatment.

The Missouri Clean Water Commission sponsored a Missouri Agricultural Inventory by Drainage Basins. For this study, county-based data was converted to drainage basins by assuming uniform distribution of activities throughout the county. The Niangua River was one basin in the inventory. It is a sub-basin of the Osage River, and composes approximately one-half of the basin as previously defined in this report. The Missouri Agricultural Inventory by Drainage Basins indicated 3.3 percent of the total land area in the basin is used for growing field crops (excluding hayland), and that 2.1 percent of the total land area in the basin which is used for field crops is on land highly susceptible to erosion.

This means that approximately two-thirds of the field crops are grown on land which has limitations due to erosion potential. In some cases, such limitations can be compensated by conservation treatment and structures, but the required management level of these lands is quite high in terms of maintaining erosion potential at a minimum.

Fertilizer application was also reported in the Missouri Agricultural Inventory by Drainage Basins. It indicated seven and four-tenths of nitrogen per square mile of total cropland or twenty-three lbs. of nitrogen per acre of total cropland was applied. This is only 25-50 percent of the fertility input necessary to promote the vegetative growth required for soil stabilization. The soils of the basin are deficient in phosphorus, and their fertility is being depleted.

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LEGEND

1	**DEEP, DARK, ROLLING PRAIRIE AREA** Gently rolling to rolling upland with deep, dark, moderat [illegible] permeable soils predominating. Some areas of limeston [illegible] outcrop occur. Small stream bottoms also occur along [illegible] utaries. Major problems are erosion and wetness. Princ [illegible] are Sharpsburg, Grundy, Summit, and Snead.
2	**UNDULATING, MIXED PRAIRIE AREA** Undulating upland with dark and moderately dark, moderately to slowly permeable soils. Significant areas of nearly level, gray, claypan prairie and poorly drained small stream bottoms are included. Some rock and shale outcrops occur on steeper slopes. Major problems are erosion and slight wetness. Principal soils are Summit, Woodson, Parsons, Dennis, Bates, and Borden.
3	**CLAYPAN PRAIRIE AND PRAIRIE SANDSTONE AREA** Nearly level to undulating upland with moderately dark colored, slowly and very slowly permeable soils. The very slowly permeable claypan soils occur on the more nearly level areas. Moderately to slowly permeable brown soils developed from sandstone and shale occur on the slopes. Slowly permeable stream bottoms are included. Major problems are erosion, wetness, and droughtiness. Principal soils are Cherokee, Carytown, Parsons, Dennis, Bates, and Borden.
4	**SANDSTONE SOIL AREA** Undulating to rolling uplands of soils of variable depth, texture, permeability and stoniness; derived from sandstone. Major problems are droughtiness, erosion, and stone content. Principal soils are Bates, Collinsville, Barco, Carytown and soils presently referred to as Bolivar and Boone.
5	**REDDISH-BROWN FOREST AND PRAIRIE SOIL AREA** Undulating to rolling and hilly soils generally moderately to slowly permeable, with silty surface soils, and cherty subsoils at 26 to 40 inch depth. Major problems are erosion, droughtiness, and flash flooding on the associated narrow bottoms. Principal soils are Newtonia, Eldon, Eldorado, and Creldon on the undulating areas and Baxter on the rolling areas.
6	**MIXED PRAIRIE AND "FLATWOODS SOIL" AREA** Undulating to gently rolling soils and associated small creek bottoms. Soils vary from light in timbered areas to dark in prairie areas. Permeability varies from moderate to very slowly permeable with fragipan horizons (hardpan) on the more nearly level areas. Surface soils are normally silty with chert content normally increasing with depth. Major problems are wetness and droughtiness with erosion on the sloping areas. Principal soils are Gerald, Lebanon, Eldon, Bado, Baxter, and Creldon.
7	**ROLLING TO HILLY CHERTY UPLANDS** Gently rolling to hilly cherty uplands and associated stream bottoms. The soils are primarily reddish brown and yellowish brown, moderately well drained soils which contain small amounts of chert in the surface and increasing with depth. Frequent limestone "glade" areas are common. Major problems are erosion, leaky ponds, droughtiness, stone content, and flash overflow on bottoms. Principal soils are Baxter, Eldon, Newtonia, Nixa, and Clarksville with loess capped Union and Winfield in this area north of the Osage River.
8	**STEEP, STONY SOIL AREA** Primarily rough stony areas with associated narrow ridges and narrow stream valleys. Slopes are steep, nearly all soils have high chert content. Most areas are in timber. Major problems are limited land use adaptability, droughtiness, stone content, and flash flooding in the narrow bottoms. Principal soils are Clarksville and Wilderness stony silt loam.
9	**BOTTOMLAND AREAS** This area outlines the approximate major valley flood plains. Soils are mixed and vary from clay to sand and gravel bars. Primarily the broader valleys (upper tributaries) are imperfectly to poorly drained silt looms and silty clays, with significant occurence of clay (gumbo). The lower reaches are narrow, and more mixed but contain higher amounts of well drained soils that are often droughty due to sandy and gravelly subsoils. Major problems are wetness, droughtiness, flooding, stream channel scour, and deposition. Principal soils are Verdigris, Lightning, Osage, Askew, Lanton, Cleora, Radley (western tributaries) and Huntington, Lineside, and Dunning in lower reaches.

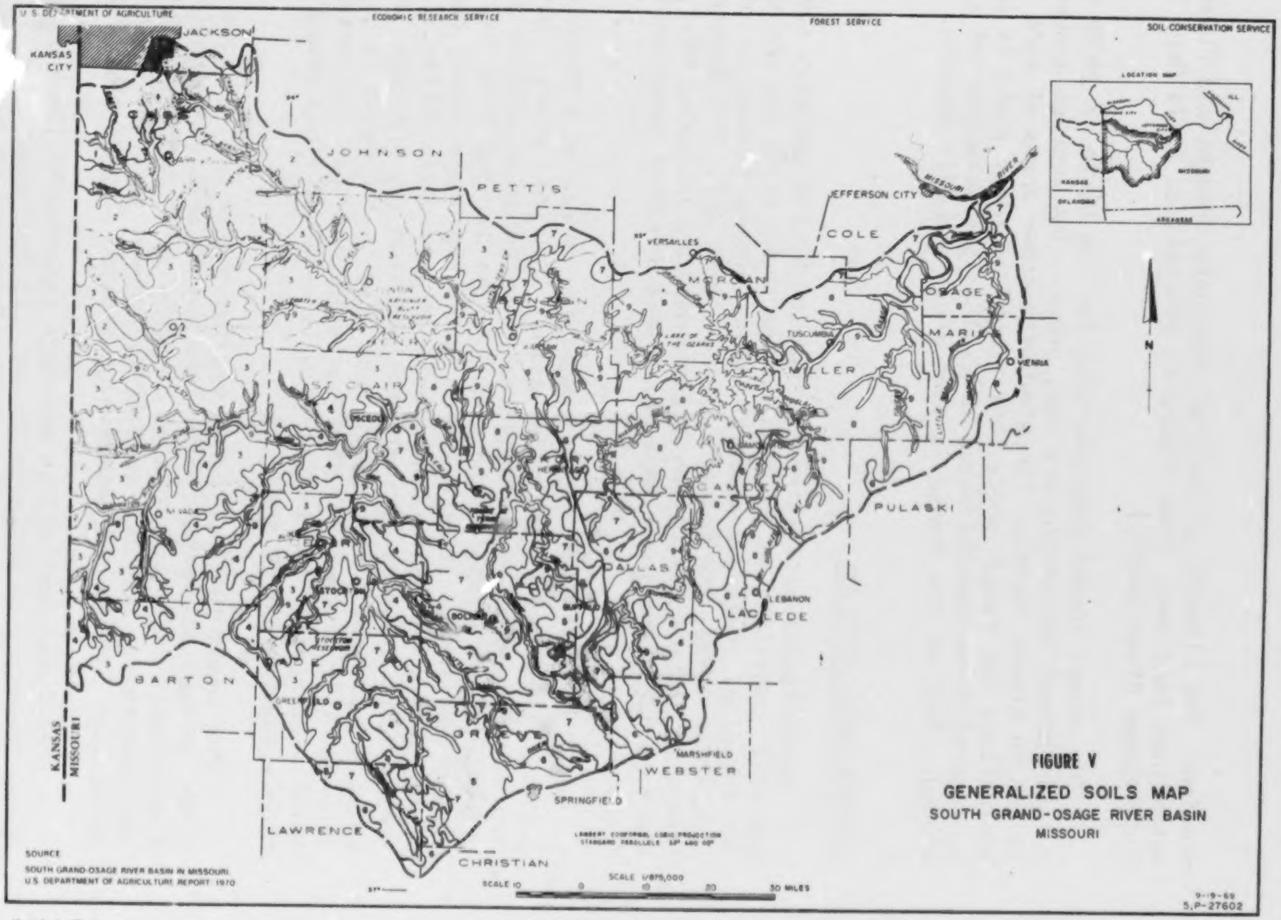


FIGURE V

GENERALIZED SOILS MAP
SOUTH GRAND-OSAGE RIVER BASIN
MISSOURI

SOURCE
SOUTH GRAND-OSAGE RIVER BASIN IN MISSOURI
U.S. DEPARTMENT OF AGRICULTURE REPORT 1970

Spring brush fire in timbered lands draining to the Lake of the Ozarks. A thunderstorm will wash large amounts of ash and sediment into the Lake afterwards. (Photo by: Don Wooldridge, Missouri Department of Conservation)

Cattle enterprises in the Lake of the Ozarks Basin are limited to cow-calf operations. The area is feed deficient, and no known commercial feedlots are in operation. However, the great demand for feeder calves in recent years has contributed to more profitable cow-calf operations. As a result, some marginal cropland is now being improved and converted to pasture. In addition, Ozark cattlemen show increasing interest in converting forest land to pasture through aerial application of herbicides or use of machinery. Much of this clearing occurs on soils or topography unsuitable for maintaining adequate grass cover. Forest sites with existing low productivity can be converted to pasture for a nominal investment, but maintenance costs could be prohibitive in areas with topography or soils unsuited for grass production. The level of management required to maintain good pasture cover on this converted, marginal cropland and forest land is quite high and, in most cases, this level cannot be maintained with existing resources.

Agriculture's share of the economy in the Lake of the Ozarks Basin will probably decrease in the future. If cow-calf operations remain profitable, more marginal cropland will be converted to improved pasture. The greatest danger of increased erosion will be from the conversion of marginal forest land into pasture. Protection as well as proper management of much of the land is needed for realization of the land's potential and employment of techniques suited to its requirements.

Degradation of water quality in the Lake of the Ozarks as a result of agricultural activities apparently is not a problem at this time. Concerning the future, the primary danger appears to be an unexpected rush to convert forest land to pasture, with a subsequent failure to establish ground cover on lands marginal for this purpose.

GENERAL DISCUSSION ON EUTROPHICATION

Effluents discharged from efficient biological waste treatment processes, although acceptable by public health standards, are usually highly enriched with mineral nutrients and often contain considerable quantities of synthetic detergent residues. The discharge of such effluents into natural watercourses and lakes results in nutrient enrichment of the receiving waters. The process of accumulation of nutrients and organic matter is known as eutrophication. Eutrophication is a naturally occurring process. Therefore, concern should be directed toward the rate of eutrophication. From the moment of its genesis, a lake accumulates nutrients and organic matter deposited by inflowing streams. Some nutrients leave a lake by flowing out in streams, by absorption through soil, or by evapoation. However nutrients continue inevitably to concentrate and, eventually, the lake becomes eutrophied.

Because the natural life of a lake may stretch over thousands of years, the process of eutrophication has not been of notable concern to the public. However, by overfertilizing watercourses, the aging of a lake is greatly accelerated. Nutrient sources such as municipal sewage, industrial wastes, agricultural drainage, and other by-products of civilization have increased the nutrient content of many beautiful recreational lakes, hastening their old age and death.

The first visible signs of eutrophication in a lake are algal blooms, which become more severe, start earlier and last longer with each year. Algal blooms are massive growths of aquatic algae which occur at or near the surface of the lake. Blooms are triggered by the existence of ideal growing conditions for algae. This involves the simultaneous existence of all minimal or better algal growth requirements such as nutrients, light temperature, trace elements, etc. At first, with food in the form of algae, fish will thrive and fishermen will be pleased. However, an algal bloom will be unsightly and foul outboard motors. As ideal growth conditions dissipate, the algae will die, and then decay. The bacterial decay will deplete the dissolved oxygen in the water and create taste and odor problems. If dissolved oxygen depletion is extreme, fish will suffocate.

Much of the literature on eutrophication places emphasis on the production of algal scums and odor nuisances, but there are other troublesome aspects of high production. Richer lakes produce more insects--mosquitoes and gnats are notable examples. Enriched waters provide a competitive advantage for rough fish over more desirable game fish. Fish kills have resulted from supersaturation of oxygen accompanied by high pH values, as well as from oxygen depletion. The more severe consequences of advanced eutrophication contribute to lowered property values and declining resort trade.

The limit of algae growth is imposed by the nutrient in least supply. The limiting factor may be physical, such as insufficient light for photosynthesis, or too low a temperature, etc. The basic elements required by aquatic algae are carbon, nitrogen, phosphorus, hydrogen, oxygen, sulfur and trace elements. Evaluation of water pollution control strategies for the control of eutrophication will depend upon the relative sources of nutrients: those sources which can be controlled _versus_ those which cannot, and control for the nutrient or nutrients which could limit algal growth.

Carbon, nitrogen and phosphorus are the primary elements evaluated as limiting nutrients. They are required in relatively large amounts to form algal protoplasm. Algae require carbon in the form of carbon dioxide (CO_2). Carbon dioxide (CO_2) is made available to natural waters from the atmosphere, carbonate alkalinity and respiratory activity.

Algae generally require nitrogen in the form of inorganic nitrate (NO_3^-), although other forms are utilizable by certain species. For example, blue-green algae can fix atmospheric nitrogen (N_2). Algae also need inorganic phosphate (PO_4^{-3}).

Nutrients enter a lake in readily available inorganic form, but they also enter bound in organic matter. Dead organic matter settles to the bottom of a lake where it is decomposed by bacteria. Consequently, large amounts of nutrients are stored in lake bottoms in the form of decaying matter and mineralized end products. A key phenomenon affecting the recirculation of this vast reservoir of stored nutrients is the thermal stratification of a lake, and its destratification which results in mixing.

The thermal history of any lake depends primarily on its geographical position and depth. The most complete annual cycle is exhibited by relatively deep lakes in temperate latitudes in which all the water is below 4° C (the temperature of maximum density) in the winter, and above 4° C in the summer. The resulting water temperature/water density distribution is characteristic of a thermally stratified lake. In such lakes of sufficient depth, as they become heated during spring from a lower temperature, the water tends to become divided into an upper layer or epilimnion of relatively freely circulating water with a small and variable temperature gradient which lies over a deep, noncirculating, undisturbed cold layer or hypolimnion. The region of rapid decrease in temperature separating the epilimnion from the hypolimnion is called the thermocline. A thermocline has been defined for convenience, though strictly on an arbitary basis, as a stratum of water in which the temperature decreases 1°C or more in the depth of one meter, or 0.55°F per foot. The decrease in temperature is accompanied by an increase in density, with corresponding increased resistance to mixing. In the hypolimnion (bottom layer), the water is protected from the atmosphere by the overlying thermocline and epilimnion; therefore, very little increase in temperature occurs after stratification is established and reaeration (renewal of dissolved oxygen) of the hypolimnion is restricted. If the thermocline is below the range of effective light penetration, as is often the case, the oxygen supply becomes depleted in the hypolimnion, since both the green plant and the surface sources are cut off.

With the onset of fall and colder weather, the temperature of the epilimnion drops until it is the same as that of the hypolimnion. The water of the entire lake begins circulating, and oxygen is again returned to the depths during this "fall overturn". As the surface water cools below 4°C, it expands, becomes lighter, remains on the surface and freezes (if the regional climate is a cold one), bringing on winter stratification. In winter, the oxygen supply is usually not greatly reduced because bacterial decomposition and respiration of organisms are not so great at low temperatures, and water holds more oxygen at low temperatures. Winter stagnation, therefore, is generally not so severe.

In the spring, as ice melts and the surface water between 0°C and 4°C becomes warmer, it also becomes heavier, reaching maximum density at 4°C, and begins to sink. The temperature of the epilimnion increases until it is the same as that of the hypolimnion. Then the water of the entire lake begins circulating, aided by wind generated turbulence, and oxygen is again returned to the depths during this "spring overturn" as nutrients are recycled to the epilimnion. As warming continues, summer thermal stratification develops. Generally, the deeper the lake, the slower the stratification and the thicker the hypolimnion. This classic picture of two seasonal overturns is typical for many lakes and reservoirs in America.

Algal nutrients are physically circulated in a lake due to thermal stratification and destratification, with the spring and fall overturns lifting nutrients from the bottom to the upper lighted zone where photosynthetic activity occurs. Nutrients are chemically circulated through food chains, and then recirculated.

Carbon dioxide (CO_2) is made available for algae from the atmosphere, carbonate alkalinity, and respiration. The major carbon reserve for aquatic plants is the carbonate alkalinity system, with inorganic carbon present as free carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3) or monocarbonate ion (CO_3). The amount of each form present is related to the hydrogen ion concentration (pH). Respiratory carbon dioxide (CO_2) is available to algae, but the respiratory activity that supplies this carbon dioxide (CO_2) also exerts a continuous demand for the oxygen produced as a by-product of algal photosynthesis. Because algae cannot carry out photosynthesis during the night hours, excess dissolved oxygen (DO) must be produced and stored in the system during the day to meet total night respiratory demand if the system is to remain aerobic. The carbon to support this excess photosynthetic oxygen production is carbon dioxide (CO_2) borrowed from the bicarbonate alkalinity during the day.

Lakes in calcareous basins have a natural source of carbonate alkalinity yielded from limestone. Any organic matter added to a lake is a potential carbon source, available when bacterial oxidation liberates carbon dioxide (CO_2).

Although the atmosphere contains 79 percent nitrogen gas, resulting in a relatively high concentration of dissolved nitrogen (N_2) in water, most algae can only take up nitrogen in the form of nitrate (NO_3) and ammonia (NH_3). However, blue-green algae do have the ability to fix N_2, when NO_3 and NH_3 are not readily available. This is a disadvantage in controlling eutrophication by limiting the NO_3 and NH_3 content of a lake, because blue-green algae are little affected by this control practice. In addition, this provides blue-green algae with a competitive advantage over other algal species. Blue-green algae are the least desirable algae because they form air pockets called pseudovacuoles within their algal cell. For this reason, when blue-green algae die, rather than sinking to the bottom, they float to the water surface and can form a decaying algal mat. Many blue-green algal species are toxic and are not generally consumed by higher life forms in the food chain. Blue-green algae in water supplies are often responsible for bad tastes and odors in the finished tap water.

An undesirable feature of eutrophication is the change in the types of algae from beneficial green algae to blue-green algae. This change in flora, characterized by blooms of blue-green algae, upsets the base of the normal food chain, resulting in the creation of new food chains that lead to far less valuable species of fish and to the accumulation of algae due to reduced grazing by herbivores.

The fact that phosphorus has received much attention as the key limiting nutrient has assisted in promoting the development of low phosphate detergents and advanced waste treatment systems for the removal of phosphorus from municipal sewage. The total phosphate in natural waters varies from less than 0.001 mg/l (milligrams per liter) to immense quantities. The total quantity depends largely on geochemical considerations, and is usually greater in waters derived from sedimentary rock in lowland regions than in waters draining the crystalline rocks of mountain ranges. The soluble phosphate usually is but a small portion, less than ten percent, of the total.

The total concentration of phosphorus at any one time may bear little relation to productivity of the ecosystem. Measurement of the concentration of dissolved phosphate in natural waters provides a very limited index of phosphate availability.

Eutrophication is a natural process for lakes, but there are control alternatives which can be instituted to slow the rate of eutrophication and extend the useful life of a lake.

1. Diverting Nutrients from Lakes. A necessary first step is to limit the fertility of the water. Where practicable, nutrients should be diverted from lakes by diverting sewage effluents and other nutrient sources. Diversion from lakes to rivers can be justified in part by the fact rivers are moving water and, therefore, have a greater ability for self-purification through mixing and aerating pollutants.

2. Removing Nutrients from Sewage. Where diversion of sewage from a lake is impracticable, the sewage should be treated for removal of nutrients. This can be accomplished by physical/chemical treatment, land disposal of secondary treatment effluent, or tertiary treatment.

3. Improving Agricultural Practices. The widespread use of commercial fertilizers may necessitate the modification of agricultural

processes to reduce enrichment of surface waters. Manure spread in winter may contribute large amounts of phosphorus as it runs off the frozen soil. The remedy is to spread manure on thawed soil. Wastes from domestic animals should be managed to prevent washing directly into streams. Erosion control should be implemented, since noneroded forest and agricultural soils have a remarkable capacity for accumulating and retaining mineral ions, especially phosphorus.

4. Removing Nutrients from Lakes. Nutrient removal efforts are applicable only to small lakes. One method is to flush the lake with large volumes of water low in nutrients. Another method is to dredge sediments high in nutrients. Harvesting large quantities of fish and aquatic plants to remove nutrients is a third method.

5. Relieving Symptoms of Eutrophication. Toxic chemicals, such as copper sulfate and algicides, have been used to kill algal blooms and water weeds.

These options are listed in order of decreasing effectiveness. Alternatives No. 4 and 5 have been used to treat lakes for temporary relief from algal blooms. Because these approaches do not really correct the root of the problem, results are usually short-lived and futile.

Clearly, the soundest preventive and restorative approach toward correcting eutrophication processes is to curb nutrient input. Every nutrient source is important and eventually must be examined for control possibilities but, first, attention must be directed toward sources for which there is currently control capability. Sewage is a major source of nutrients for which control technology is now available. The first consideration, and most effective, is to divert sewage from lakes to less susceptible waters. Unfortunately, many locations lack favorable watercourses to receive diverted sewage flows, and their only recourse is nutrient removal from sewage.

The next question is what nutrient or nutrients should be removed. Much research by various investigators has been directed toward determining the minimum nitrogen and phosphorus concentrations which would permit the growth of algae.

The suggested critical measurable levels for eutrophication of 0.01 mg/l inorganic phosphorus and 0.30 mg/l inorganic nitrogen should be used cautiously as guidelines, because of the ability of algae to grow in the presenceof suboptimal concentrations of nitrogen and phosphorus. The luxury uptake of excess phosphorus by algae presents the possibility of algal blooms occurring when measurable phosphorus levels are below critical levels, or not even detectable. The nutrient requirements in an impoundment environment, with respect to nitrogen and phosphorus, are further complicated by the recycling of nutrients caused by death and decomposition of algae. Other complicating factors are the nitrogen fixation ability of certain algae and the varying nitrogen and phosphorus requirements of different species of algae. Nitrogen may become a limiting nutrient only because of the slow rate at which organic nitrogen deposits may be degraded.

A result of fundamental knowledge, coupled with conclusions from scientific study and experience with lake studies, is that most researchers agree limiting phosphorus availability in lakes is the single most important step necessary for eutrophication control. Human activities which contribute phosphorus to surface water are the significant cause of declining nitrogen/phosphorus ratios. Therefore, this growing imbalance can be corrected only by appropriate adjustment in human affairs. Municipal sewage is the major point source, and all such discharges to lakes and other susceptible waters should be treated to reduce phosphorus content to realistic target levels. Nutrient budgets should be established for all major lakes to facilitate curtailing nutrient inputs from all diffuse and point sources. All inputs are additive and, therefore, potentially significant. Once the major inputs are effectively controlled, the naturally occurring concentrations of calcium, aluminum, iron and other essential elements will not create a serious problem.

ENVIRONMENTAL IMPACT OF TRUMAN DAM ON THE LAKE OF THE OZARKS

A comprehensive evaluation of the environmental impact of the Harry S. Truman Dam and Reservoir project was prepared by the U.S. Army Corps of Engineers, Kansas City District, in accordance with the National Environmental Policy Act of 1969 (PL 91-190). Material relating to the Lake of the Ozarks has been abstracted from the Corps' Harry S. Truman Dam and Reservoir Environmental Impact Statement dated January, 1973, for this report.

IMPACT OF THE IMPOUNDMENT

Water Quality

1. The Truman Reservoir would act as a large settling basin above the Lake of the Ozarks and would reduce the sediment loading to the Lake of the Ozarks, helping to stabilize the Lake's water level. The Osage River carries a moderate sediment load with a mean suspended sediment concentration at Osceola of about 700 parts mg/l. During periods of high runoff concentrations usually approach 2,000 mg/l, with concentrations as high as 4,000 mg/l observed. The Truman Reservoir contains approximately

4,000,000 acre-feet of flood control storage. When a high inflow with attendant high turbidity levels enters the reservoir, the longer retention time will promote suspended particle sedimentation. The Lake of the Ozarks has proportionally little flood control storage. Therefore, high inflows and subsequent high releases draw the turbid inflow far into the Lake.

2. The temperatures of the released water from the Truman Reservoir would be within the acceptable rangeof normal stream water temperatures and would meet the Missouri Water Quality Standards. Estimates of thermal stratification of the Truman Reservoir were computed by the Corps of Engineers. They found that the released water temperature would be approximately 70° F in early June, with a temperature differential of about 6° F from surface (elevation 706.0 ft. m.s.l., multipurpose pool) to the top of the skimming weir (elevation 660.0 ft. m.s.l., or 46 feet deep) at the end of the month. There are several reasons for this limited stratification of 6° F compared with the Lake of the Ozarks, which sometimes has a temperature differential of 10° to 15° F from the surface to 46 feet in depth. First, the storage in the Lake of the Ozarks is about twice that of the storage in the multipurpose pool of the Truman Reservoir. In addition, the Lake power withdrawal zone is about 76 feet below the surface, whereas the Truman Reservoir power withdrawal is 46 feet below the surface. The 46-feet depth at Truman Reservoir is based on a topographical restriction left in place upstream of the power intake at elevation 660.0 feet m.s.l. This will serve as a natural skimming weir which will require the water released through the power units to be drawn from above elevation 660.0 feet m.s.l. As a result, the released water will have an adequate supply of dissolved oxygen.

3. Except for the differences related to thermal stratification, the chemical water quality of the Truman Reservoir would be about equal to that of the Lake of the Ozarks, since the inflow water into Truman is essentially the present inflow into the Lake of the Ozarks. Various chemical parameters such as dissolved oxygen and carbon dioxide are distributed vertically according to temperature. Consequently, chemical quality of water in Truman, as in the Lake of the Ozarks, would vary with depth and time of year. Since permanent stratification is not indicated for Truman at the elevations from which power releases would be drawn, the by-products of anaerobic conditions, such as hydrogen sulfide and ammonia, would not be present in the releases from the Truman Reservoir.

4. During initial filling and prior to completion of the power facilities, a thermal stratification condition would develop which would be considerably different from that for normal operations, described previously. The water temperature of the releases from Truman Dam during this period would be about the same as that of the Lake of the Ozarks at Warsaw, Missouri. The oxygen content of the releases would be near saturation, since releases would be withdrawn from the top of the lake. As the water level rises in Truman Reservoir, more

vegetation would be inundated. The biochemical oxygen demand derived from the newly inundated vegetation would be sufficiently high to deplete the oxygen levels below the thermocline in Truman Reservoir. In the epilimnion, the area above the thermocline, both water temperature and dissolved oxygen concentrations would be fairly homogenous throughout the Lake.

5. During periods of flood storage, the dissolved oxygen concentrations in the upper reaches of the Truman Reservoir may be decreased, due to introduction of organic matter associated with flood flows into that portion of the Lake. A reduction of dissolved oxygen concentrations has been observed in the upper reaches of the Lake of the Ozarks following periods of high inflow. These concentrations have not been sufficiently low to degrade the water quality of the Lake of the Ozarks. If oxygen concentrations are reduced in the upper reaches of the Truman Reservoir during flood storage periods, these concentrations would not be low enough to cause any water quality problems.

Aquatic Ecosystem

1. Phytoplankton productivity is relatively high in the Osage arm of the Lake of the Ozarks. This is probably due to the nutrients absorbed from the incoming sediment load which are released for phytoplankton productivity. Normally, the suspended sediment decreases light penetration which, in turn, restricts primary production. Apparently, the increase in nutrient level allows a plankton population to thrive in a limited zone of light penetration. The power releases from the Truman Dam would contain less suspended sediment, resulting in both lower turbidity and lower nutrient levels in the Osage arm. The decrease in turbidity would increase the zone of light penetration, but the decrease in available nutrients probably will restrict the amount of phytoplankton productivity. Therefore, it is anticipated the resulting primary production would be about equal to that under present conditions.

2. The Harry S. Truman Dam will reduce the severe water level fluctuations now occurring in the Lake of the Ozarks. The Lake's operation schedule requires a three-feet reduction in the power pool elevation at the start of the spring flood season to alleviate flood problems downstream. Present operational restrictions imposed by the Federal Power Commission at the Lake of the Ozarks require the pool level to be maintained at or below elevation 657.0 feet, m.s.l., during March, April, and May for flood control purposes. The result of this regulation is an annual water level fluctuation of three to eight feet during the spawning season for most fish in the Lake. The Harry S. Truman Dam and Reservoir flood control storage operation will regulate floods so the three-feet seasonal drawdown may not be necessary in the Lake of the Ozarks. This action would improve the fishery by providing a more stable water level and by benefiting those fish, such as bluegill, whose reproductive cycles require a nonfluctuating water level.

Resorts on the Lake of the Ozarks would also benefit from the more stable pool. It has been recommended the Union Electric Company, operator of the Lake, request the Federal Power Commission to lift the three-feet restriction upon completion of the Truman project.

3. Since 1967, striped bass have been stocked in the Lake of the Ozarks, the only reservoir in Missouri considered to have a potential for an extensive self-sustaining striped bass fishery. In 1971, these fish began to appear in the fish catch of the Lake. Striped bass require extensive areas of flowing water upstream from a reservoir for spawning. Another factor in striped bass reproduction is that the eggs must remain buoyant in the stream long enough to hatch before they reach the slack lake water where they settle to the bottom and die. Therefore, water temperature, the velocity of the stream, and the amount of stream mileage above the Lake are very important to egg hatching success. To date, there has been no attempt to document spawning, nor has there been any report of natural striped bass spawning occurring in the Osage River above the Lake.

Following completion of the Truman Dam, it is questionable whether striped bass would be able to use either the Niangua or the Little Niangua Rivers for spawning. Since the Osage River is the only tributary of the Lake large enough for a striped bass spawning habitat, completion of the Truman Dam will eliminate the chances for establishing a self-sustaining population of striped bass in the Lake of the Ozarks.

4. The Truman Reservoir would inundate those areas where paddlefish spawn in the Osage River. Areas equivalent to those where paddlefish now spawn are not known to exist in the Osage River Basin beyond the proposed Truman Reservoir. Studies completed by the Missouri Department of Conservation show several small gravel bars in the Marais des Cygnes and Sac Rivers which might be suitable paddlefish spawning sites. It is possible paddlefish would spawn in these marginal spawning areas after project completion, but the numbers of fish provided by smaller spawning sites would not maintain a fishery of the size currently in the Osage River. This fishery is presently used by many sport fishermen and, each year, between 18,000 and 23,000 fishermen partake in paddlefish snagging during the two-month snagging season between March 15 and May 15. Most of the fishing occurs in the Osage River between Warsaw and Osceola, Missouri.

Paddlefish would persist in Truman Reservoir several years after completion of the project. However, unless methods are developed for artificial propagation or artificial spawning grounds, or until natural spawning grounds are developed in the Sac arm, Pomme de Terre arm, or Osage headwaters prior to impoundment, the fishery will be unable to sustain its present size due to insufficient recruitment of population. Artificial techniques for maintenance of the present paddlefish population are unknown and would have to be developed. Such techniques probably could not be developed by the proposed closure date for Truman Dam. If any recruitment occurs, from either natural or artificial reproduction, limited areas in the upper reaches of Truman Reservoir might harbor concentrations of paddlefish available for fishing purposes. During the spring spawning season, small concentrations of paddlefish may also occur in the tailwater immediately below Stockton and Pomme de Terre Lakes. However, these areas may not prove successful for paddlefish propagation.

Following completion of the project, a temporary paddlefish sport fishery would exist in the tailwater of the Harry S. Truman Dam. This fishery would persist for several years, but would eventually diminish without recruitment from the paddlefish population of the Lake of the Ozarks.

Completion of the Truman Dam would terminate or substantially reduce the unique sport fishery of a large population of paddlefish in the upper Osage River Basin.

The construction of the dam will result in a substantial decline or loss of the sport fishery provided by the spawning migration of walleye from the Lake to reaches of the Osage River. Although these spawning areas would be eliminated, it is anticipated walleyes would spawn in other areas in both the Lake and Truman Reservoir, or in large tributaries of these lakes containing suitable spawning substrate. The walleye does not specifically require running streams for spawning, but requires primarily a rock-rubble substrate for egg deposition. The walleye can use areas other than exposed gravel under flowing water for spawning. Walleyes are successfully spawning in a number of impoundments in the midwest, such as Tuttle Creek Lake, Kansas; Lake Maloney, Nebraska; and Canton Lake, Oklahoma. The spawning in these lakes is mainly in areas where a rubble substrate adjoins the shoreline, or along riprap on the face of the dam embankment. The number of fish from reproduction in the areas is sufficient to sustain the walleye fishery. From this information, and from evaluation of bed substrate data in tributary streams, it is anticipated there would be various possible spawning areas in both the Lake of the Ozarks and Truman Reservoir. Two tributary streams of the Lake, Niangua and Auglaize Rivers, have a bed substrate of rubble, gravel, and rock. Walleyes have been collected in these streams; therefore, these waterways should support walleye reproduction. In addition, limited stretches of suitable rubble or rock outcroppings in various areas of the Lake of the Ozarks could be used for walleye spawning.

IMPACT OF PUMPED STORAGE POWER GENERATION OPERATIONS

Water Levels

1. The Harry S. Truman Dam and Reservoir project is designed to generate an average of 282 million kilowatt-hours of electrical energy annually. Most of this energy would be produced for existing and projected peak power demands during summer months, June through September. To maintain the desired water level differential between the two lake surfaces, the project will require electrical energy generated by other plants during off-peak power demand periods for the pumping of water from the Lake into the Reservoir.

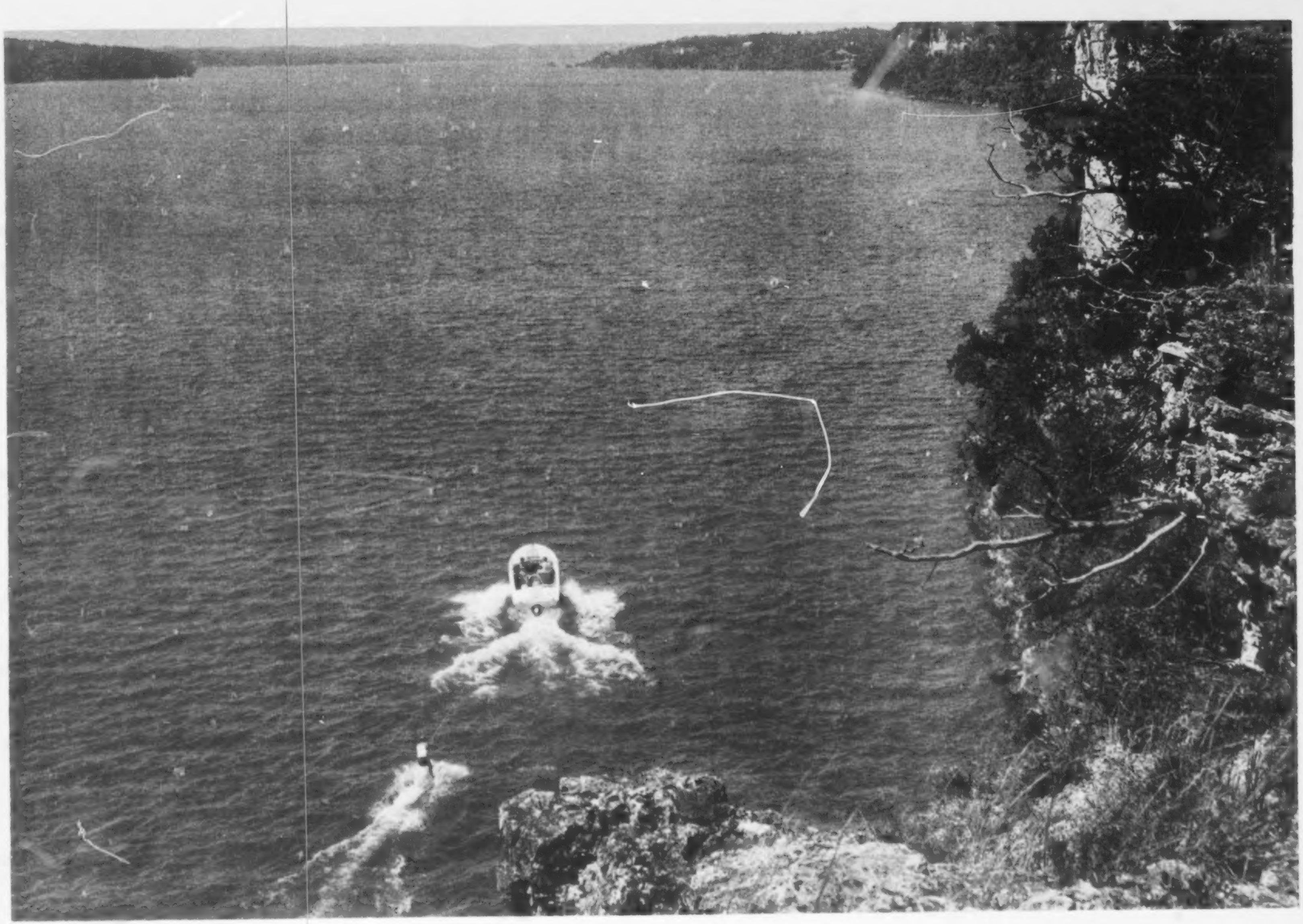
2. The hydroelectric power plant at the Truman Dam would supply electrical energy annually during the peak demand period, June through September. The generation period would average seven hours each day, five days each week. During periods of insufficient inflow, the generators and turbines would be reversed and return water from the Lake to Truman Reservoir. Pumping would be accomplished with available off-peak power during eight hours at night, with a maximum of 40 hours on weekends. It is assumed the weekly net releases from Truman Reservoir would supply most of the minimum releases from the Lake of the Ozarks.

3. Operation of Harry S. Truman Dam and Reservoir would affect the water levels in the Lake of the Ozarks. Net releases from the reservoir would average a daily rate of 450 c.f.s. with the power releases ranging from 54,000 c.f.s. to 63,000 c.f.s. The frequency with which these release rates would affect the Lake would vary somewhat, depending on the power demand pattern set for the system. During a 40 hour weekend of pumping, 93,000 acre-feet could be withdrawn from the Lake into Truman Reservoir. At this rate, the normal pool level of the Lake would be reduced by one and one-half feet. To evaluate a realistic drawdown imposed on the Lake of the Ozarks by the pump-back operation, a study was made for a 28-year period of record. This study revealed the full 40 hours of pump-back would occur on only six weekends. Averages by months and the effect on the Lake are shown in the following table:

EFFECT OF PUMP-BACK OPERATION ON THE LAKE OF THE OZARKS

	June	July	August	Sept.	Season
Average acre-feet pumped per weekend	12,900	16,200	32,000	32,800	23,500
Lake of the Ozarks draft in feet	0.23	0.28	0.56	0.57	0.41

Source: U.S. Department of Army, Corps of Engineers, Kansas City District; Harry S. Truman Dam and Reservoir Environmental Statement; January, 1973.



Boating and Water skiing on the Lake of the Ozarks.
(Photo by: Walker-Missouri Tourism Commission)

4. Power releases from Harry S. Truman Dam would increase the elevation of the slack-water pool in the Lake of the Ozarks immediately downstream from Truman Dam by four to five feet within a five-hour period. Model tests by the Corps of Engineers show the rise would occur as follows: fifty percent in one hour; seventy-five percent in three hours; and one-hundred percent in five hours. The rate of fall would be twenty percent in one hour, fifty percent in three hours, and ninety percent in six hours. The amplitude of this pool fluctuation would decrease with distance downstream from Truman Dam. At the U.S. Highway 65 Bridge at Warsaw, the change in pool elevation would be about one foot less than at the Dam. There would be negligible pool fluctuation due to power releases 17 miles downstream from the Dam. Although the recreational value of the Osage River immediately downstream of the Dam would be reduced because of the power releases, the Lake of the Ozarks backwater area below this point would be changed from a rather murky sediment-laden area to an area containing relatively clear water. It is anticipated good warm-water fishing would be generally available, in addition to opportunities for boating and other water-oriented activities. The Corps of Engineers plans to make a study of the immediate downstream area to determine specific means to mitigate adverse effects caused by the project.

CONCLUSIONS

Based upon the foregoing information, the following conclusions can be drawn regarding present and future water quality of the Lake of the Ozarks:

1. The quality of the water, as measured by reliable and usually acceptable indices of organic pollution (i.e., dissolved oxygen and biochemical oxygen demand) is good and at expected levels for natural waters relatively free from waste discharges.

2. In all cases, the intensive bacteriological sampling showed the bacterial numbers were significantly lower than those of standards established by the State of Missouri for water contact sports.

3. The occurrence of nuisance plant growths, including rooted plants and algae, was not reported or detected. Biological studies indicated a mesotropic or moderately enriched condition, rather than a eutrophic or well enriched condition. A limiting factor appears to be a lack of phosphorus, or its occurrence in an unusable form.

4. The construction of the Harry S. Truman Reservoir will improve water quality in the Lake of the Ozarks, mainly by removal of suspended sediment. While not degrading water quality, the Dam will have detrimental effects upon certain species of fish, such as the paddlefish,

walleye, and striped bass through disturbance or elimination of their spawning areas.

The plans of action for protection and enhancement, where possible, of the water quality of the Lake of the Ozarks are presented in other chapers of this report.

CHAPTER V

EXISTING SEWERAGE FACILITIES

MUNICIPAL COLLECTION AND TREATMENT SYSTEMS

Warsaw, Camdenton and Linn Creek are the sole municipalities with collection and treatment systems for sanitary wastes. All other communities in the Lake of the Ozarks Region use individual systems such as septic tanks, sand filters, small lagoons, etc. None of the municipalities has storm sewers or combined systems. Sources of municipal wastewater are shown in Table V-A.

TABLE V-A

SOURCES OF MUNICIPAL WASTEWATER

LAKE OF THE OZARKS REGION

Municipality	1970 Population	Type Treatment Facility	Discharge Point
Warsaw	1,407	Lagoon and Disinfection (Under Construction)	Osage River
Camdenton	1,616	Lagoons	Linn Creek & Tributaries
Linn Creek	264	Septic Tanks	Linn Creek

1. Warsaw. Construction of new facilities began in 1973, with completion scheduled for mid-1974. Facilities consist of a three-cell lagoon and disinfection facilities.

2. Camdenton. Present lagoons have adequate capacity but do not have capability for nutrient removal.

3. Linn Creek. Present facilities do not provide adequate treatment. The village is listed on the State's Abatement Needs and Schedule, Interim Basin Plan, Osage Gasconade River Basin, though it is not included on the one-year or five-year priority list.

PRIVATE COLLECTION AND TREATMENT SYSTEMS

The Holiday Inn Motel, Mai Tai Motel, Lodge of the Four Seasons, and Tan-Tar-A operate and maintain collection and treatment systems (Table V-B). The remainder of the resorts, cabins, motels, etc., use septic tanks, sand filters, small lagoons, or a combination of these. Pertinent data are presented in Table V-B.

TABLE V-B

MAJOR SOURCES OF NON-MUNICIPAL WASTEWATER (RESORTS/MOTELS)
1973
LAKE OF THE OZARKS REGION

Resort	Number of Units	Estimated Maximum Population	Type Treatment Facility	Discharge Point
Holiday Inn	211	460	Activated Sludge	Lake of the Ozarks
Lodge of the Four Seasons	300	500	Activated Sludge	Lake of the Ozarks
Land of the Fifth Seasons	Max.-750 Houses	Max. Probable 2,250	Activated Sludge	Lake of the Ozarks
Tan-Tar-A	231	470	Activated Sludge	Lake of the Ozarks
Tan-Tar-A Estates	156	350	Activated Sludge	Lake of the Ozarks

It is not the intent of this publication to provide a detailed analysis of wastewater treatment methods. A thorough discussion of systems employing activated sludge, trickling filters, lagoons and physicochemical processes may be found in technical literature. Such systems are generally installed by contractors working under professional engineering supervision. State, federal and local regulations govern their installation and operation. These types of treatment are not widely used by small firms, or on home or cabin sites. If their use is contemplated, inquiry must be made of the Missouri Clean Water Commission and proper procedures followed before design and installation.

However, septic tank systems have been widely used since their introduction into the United States almost 100 years ago, especially by small firms and on individual lots. Although providing the advantages of modern plumbing in isolated rural areas, use of septic tanks has also introduced increasing problems associated with their operation in more densely populated areas.

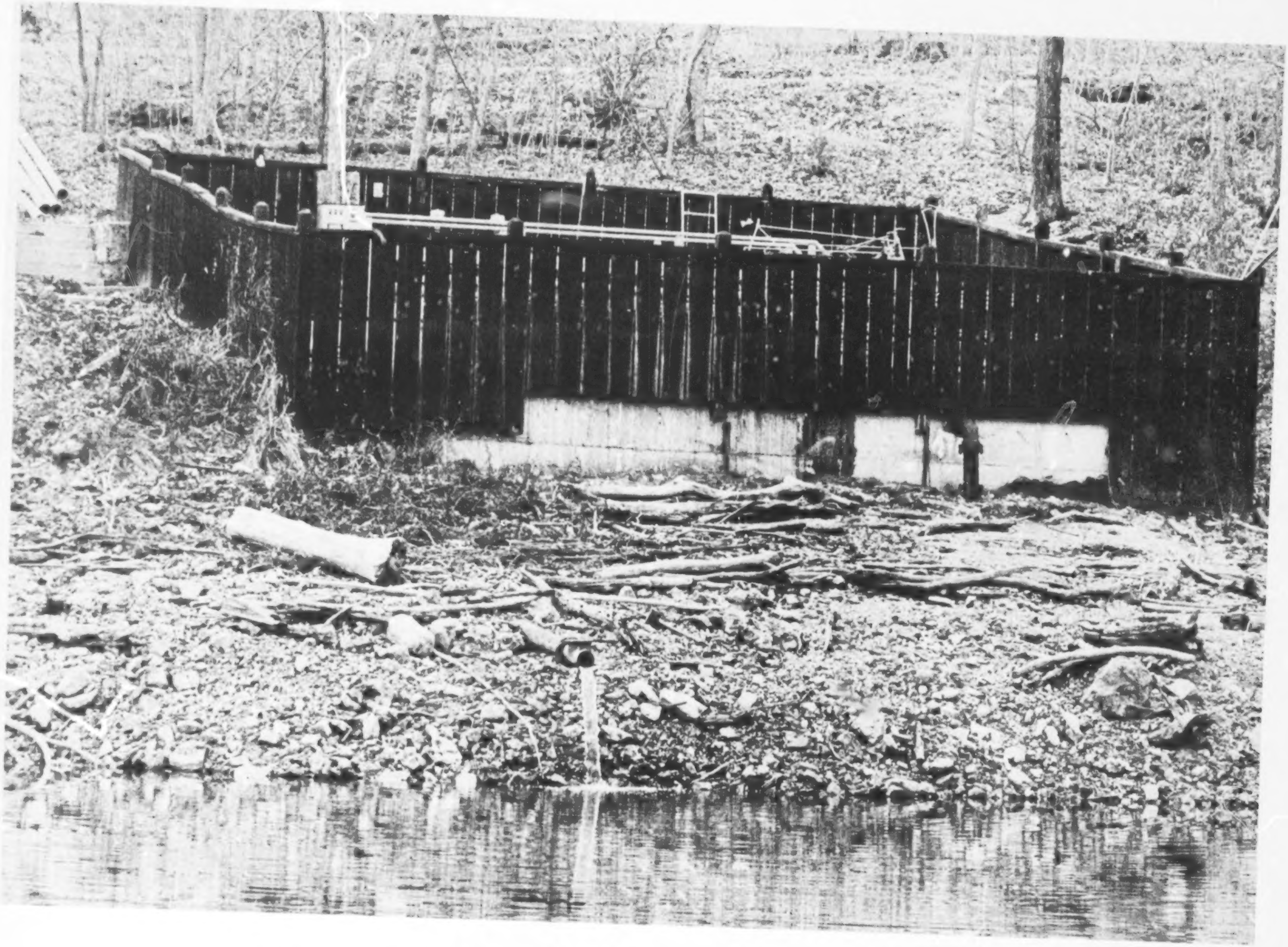
When site conditions are suitable, a well designed, constructed and operated septic tank and drain field is the most feasible method of sewage treatment and disposal for the household not connected to a municipal sewerage system. Newer methods of treatment and disposal for individual households, such as chemical toilets, small package-type treatment units, and incinerators have been developed but have not yet been adopted on a large scale. During their 100 years of usage in the United States, septic tank systems have remained basically unchanged. Essentially, the method provides for the collection of waterborne household wastes in a buried vault where scum, grease, and settleable solids are removed from the liquid by gravity separation. The retained solids are digested by bacterial action and partially liquefied; the effluent liquid drains into a subsurface drain field where it percolates into the soil.

Satisfactory operation of a septic tank system depends on the character and extent of the soil mantle, the depth to the groundwater table, size and slope of the lot, the rate of hydraulic loading, the strength and chemical characteristics of the waste, the extent of periodic maintenance, and the system's location in relation to streams, wells and structures. Frequently, one or more of the parameters for satisfactory operation of a system is not met, resulting in unsatisfactory operation and endangering public health.

The U.S. Public Health Service and the Missouri State Division of Health have established regulations and recommendations for septic tank systems. Local regulations are often nonexistent, and lack uniformity. Requirements have also been established by the Federal Housing Authority and the Uniform Plumbing Code. Some comparative septic tank system and setback requirements are shown in Tables V-C and V-D.

The U.S. Public Health Service (USPHS) has been responsible for much of the literature published on the subject of septic tanks and has conducted and sponsored research in this field. Its publication, Manual of Septic Tank Practice, is the basic reference for septic tank and drain field design. USPHS requirements for septic tank systems and those of other organizations are shown in Table V-C.

The Missouri State Division of Health (MSDH) exercises general supervision and control of all phases of public health work in the State through development of standards and issuance of regulations. The Division has published a pamphlet entitled Guide for the Construction of Individual Water Supply and Sewage Disposal Systems which presents recommended practices covering septic tank and drain field construction in areas where municipal sewerage is unavailable.



Typical small prefabricated sewage treatment plant discharging directly to the Lake of the Ozarks. (Photo by: Ferguson, St. Louis Post-Dispatch)

TABLE V-C

COMPARATIVE SEPTIC TANK SYSTEM REQUIREMENTS

	REQUIREMENTS			
	FHA(1)	USPHS(2)	UPC(3)	SDH(4)
Minimum Septic Tank Sizes (Gallons)				
1-2 Bedrooms	750	750	750	750
3 Bedrooms	900	900	1,000	1,000
4 Bedrooms	1,000	1,000	1,200	1,000
5 Bedrooms	1,250	1,250	1,500	-
Gallons per additional bedroom	250	250	150	250
Drain Fields				
Percolation test required	Yes	Yes	No	Yes
Surface used for design	Bottom	Bottom	Bottom	Bottom
Trench width required (in.)	12-36	12-36	18-36	18-36
Minimum gravel depth below tile (in.)	6	6	12	6
Area of Trench Bottom Per Bedroom (Minimum)(Sq. Ft.)				
15 Minutes per in percolation rate	71(5)	71	30	190
30 Minutes per in percolation rate	94	94	45	250
60 Minutes per in percolation rate	124	124	(6)	330
Minimum Trench Spacing (Ft.)	6	6	6	6.5

Notes:
(1) Federal Housing Authority
(2) United States Public Health Service
(3) Uniform Plumbing Code
(4) Missouri Division of Health
(5) Assumes 2-ft. trench depth and 18-in. trench width
(6) As required by Health Department

TABLE V-D

COMPARATIVE SETBACK REQUIREMENTS FOR SEPTIC TANK SYSTEMS

	REQUIREMENTS (FT.)		
LOCATION	FHA(1)	UPC(2)	SDH(3)
Septic Tank To			
Buildings	5	5	5
Property Lines	10	5	10
Wells	50	50	50
Streams and Lakes	--	50	75
Water Lines	10	5	--
Drain Fields To			
Buildings	5	8	15
Property Lines	5	5	10
Wells	100	50	150
Streams and Lakes	--	50	75
Water Lines	10	5	--

(1) Federal Housing Authority
(2) Uniform Plumbing Code
(3) Missouri Division of Health

A reasonably useful life for a septic tank system is achieved only through the application of strict design criteria, the utilization of the best construction practices, and the establishment of an effective, continuous program of surveillance and maintenance. However, consideration should be given in advance to ultimate failure and provision for corrective measures.

In developing areas, septic tanks may be suitable in some cases on an interim basis where provision has been made for future connection of the area to municipal sewerage systems. In some locations, the soil is unsuitable for septic tank systems and limitation of or prevention of residential or commercial development is necessary.

Site Suitability. Before installation of a septic tank, the site must be found suitable from the standpoint of soil characteristics, lot size and topography. Acceptable soil within the drain field area should have a minimum of 5 feet in depth and the level of the seasonal high water table should be at least 3 feet below the bottom of the proposed drain field trench. A site subject to flooding is unsuitable. Topography should permit gravity flow through the entire process. Soil borings should establish the depth, extent and character of the soil mantle, and the location of bedrock or other impervious strata. Generally, such an investigation should reasonably define the site characteristics within the upper 8 feet.

Investigations should be conducted to confirm that the soil possesses sufficient percolative capacity to support the leaching process. Lot size requirements for septic tank systems depend greatly on soil characteristics (as discussed above), but a minimum lot size of one acre, with proper soil conditions, should be adequate, if slopes are not too steep. The lot size requirement should provide for standard setbacks and desirable location of the residence. To prevent public health problems, the septic tank system components should be located a safe distance from water supply sources.

Protection of Water Supply. While public ownership of all watershed lands is undoubtedly the most satisfactory method of safeguarding the quality of a public water supply, such a course is not always possible. Several major water supply reservoirs in the Study Area are presently faced with the threat of pollution from residential development of watershed lands the water supply agency does not own. Where septic tank systems are proposed for these lands, the potential hazard to a public water supply justifies the adoption of more stringent requirements.

To eliminate any danger of bacterial contamination in reservoirs, it is necessary for septic tank effluent to travel a sufficient distance through the soil mantle. Approximately 150 feet is recommended as the minimum setback distance from any point in the septic tank system to the nearest cut, embankment, permanent or intermittent stream, or other point where the effluent might surface.

Special care should be taken to ensure the minimum depth of soil to bedrock or other impervious strata is available. Where bedrock is loosely bedded or heavily fractured, consideration should be given to a further increase in setback distances. A regular program of drain field inspection, supplemented as necessary with bacteriological testing of adjacent reservoir and tributary streams, and the implementation of requirements discussed above should eliminate the risk of reservoir contamination until municipal sewerage service is provided.

A review of the areal geologic conditions indicates that, in general, the Study Area has few, if any, sites suitable for septic tank systems. Lot size makes proper isolation impossible, as a rule. Therefore, septic tank systems as presently designed and installed should not be included in any long range plan for a wastewater management system.

CHAPTER VI

QUANTITY AND QUALITY OF SEWAGE FLOWS

INTRODUCTION

Before it is possible to design a sewerage and treatment works system and estimate its cost, the quantity of wastewater to be collected, conveyed, and treated must be determined. In addition, the quality (a general term to describe the strength or composition of sewage or wastewater) must be evaluated. This chapter reviews general methods of describing or estimating quantities and quality of wastewater for use in design of a collection and treatment system.

QUANTITY OF WASTEWATER FLOWS

When a sewerage system is designed for an area without existing sewers, it is necessary to estimate the quantities of wastewater to be collected, since measurement of flows is impossible. In fact, if parts of the service area are uninhabited at the time of sewer construction, no flows would exist.

In general, sewage flow estimates of water usage can be made when a water system exists and flows are either metered or measured to facilitate individual or per person estimates of usage. Since there is no system in the Ozarks Study Area, records of flow are unavailable. However, many records of water and wastewater usage and production from comparable areas are available on which estimates can be based.

A survey of literature and records on wastewater flows indicates per capita generation of wastewater varies from less than 50 gallons per day to over 500 gallons per day. The lower values appear to be from systems serving areas with large amounts of substandard, low value property and residents with very low living standards, or from areas with poor quality and/or shortages of water. Larger values derive from systems serving industrial or commercial areas, from sizeable areas of high cost housing with high living standards. Higher values also are from systems so constructed that water enters through poor pipe joints, cracked pipes, poorly constructed manholes or inspection wells, basement or foundation drains, or roof downspouts. Included under the latter would be the deliberate acceptance of storm water through street and yard drains. Sewers which accept rainwater from roofs, streets, groundwater from foundation drains, and similar sources are termed combined sewers, in contrast with those carrying only domestic, sanitary or industrial flows, called sanitary or separate sewerage systems.

A publication intended as a guide for the design, construction, and operation of sewerage works for the State of Missouri states:

"In general...the reviewing authority will approve plans for new systems, extensions, or replacement sewers only when designed upon the separate plan, in which rainwater from...are excluded."[3] Therefore, it is understood any sewerage system approved for the Lake of the Ozarks Study Area would be a separate or sanitary system.

Subparagraph 24.1 of the above quoted document establishes design flows at 100 gallons per capita per day. However, to allow for normal inflow, leakage and peak periods expected in a well constructed system, certain elements such as laterals, submains, and trunk sewers can be designed to carry flows from 250 to 400 gallons per capita per day. To protect basements or dwellings in lower areas, interceptors should not be designed with a capacity for less than 350 gallons per capita per day.

The following paragraphs from A Guide for the Design of Sewage Works published for the State of Missouri establish the basic design quantities of flow: Paragraph 24, Subparagraph 24.1, 24.11, 24.12, 24.13 and 24.2.

QUALITY OF WASTEWATER FLOWS

Although sewage is approximately 99.9 percent water, the remaining 0.1 percent consists of solids, either in solution or suspension. Fresh domestic sewage has a slightly soapy or oily odor and is cloudy in appearance, resembling a soapy solution. It is sometimes described as resembling dishwater with floating bits of garbage, paper, matchsticks, soap, rags, lumps of fecal and other miscellaneous matter. It is this 0.1 percent which must be removed or rendered less harmful in a wastewater treatment system.

Certain physical or chemical tests have been employed to determine the characteristics or quality of sewage and the accomplishments or efficiencies of waste treatment works. In a system collecting and treating wastes from an area of residential, recreational, or light commercial uses (with little or no industrial uses), the two tests most effective and meaningful are the Suspended Solids (SS) and the Biochemical Oxygen Demand (BOD) tests.

Suspended solids either float on the surface of or are suspended in wastewater. They are important, not only from an aesthetic standpoint, but also as a source of organic matter in the water. Generally, they are measured in parts per million (ppm) by weight--or milligrams per liter (mg/l). Typical domestic or sanitary sewage generally has an SS content of from 100 to 200 mg/l (ppm).

Biochemical Oxygen Demand measures the amount of oxygen required by organisms to stabilize or reduce organic material to relatively inert or harmless inorganic material. BOD is also measured in ppm (by weight) or mg/l, and represents the dissolved oxygen taken up by the organisms in their processes of reducing the organic material. The BOD of domestic or sanitary sewage is about 100 to 200 mg/l (ppm).

With water at usual temperatures containing from 7 to 14 mg/l dissolved oxygen, it becomes apparent that if the BOD of the wastes exceeds the total oxygen available in the receiving waters, the oxygen supply of the water is depleted. As a result, fish and other oxygen demanding life (called aerobic organisms) die, and the body of water becomes a lifeless, foul-smelling liability.

Requirements for treated effluents entering the lake or tributaries are strengths lower than 20 mg/l of BOD and 20 mg/l of SS, according to the Missouri Clean Water Commission. In other words, the treatment plant must remove from 80 to 180 mg/l of the SS and from 80 to 180 mg/l of the BOD.

The regulations for SS and BOD concentrations do not protect the health of the water user per se. However, protection of fish and other aerobic aquatic organisms is ensured, and the aesthetic qualities of the body of water are preserved. Disease producing bacteria will be reduced, but not to acceptable levels.

Raw or untreated domestic sewage contains from one to one hundred million coliforms per one hundred milliliters. (One hundred ml equals approximately one-third of a teacup.) This is the fecal form count. Before laboratory techniques were refined, tests yielded only total coliform counts, and in the older literature and specifications, total coliform counts of from 1,000 to 2,000/100 ml were allowed. These total coliform counts have been superseded by the fecal form count. (The coliform group of bacteria inhabits the intestines of man or animals. Occasionally, they are found elsewhere, for example, in the soil and on plants.)

The Missouri Clean Water Commission requires fecal coliform organisms in water not to exceed 200 per 100 ml. Therefore, some form of disinfection is necessary. The one most commonly used today is chlorine, or a chlorine compound. Other disinfectants are available, but simplicity, ease of application, and cost usually dictate some form of chlorination.

Domestic wastes also contain plant nutrients, commonly referred to as fertilizers. The chief nutrients are nitrogen (N) and phosphorus (P). Land runoff also contains these elements, sometimes in great quantities if the lands have been subject to artificial fertilizer applications. Domestic sewage contains from 15 to 20 mg/l of total nitrogen, and from 5 to 15 mg/l total P, expressed as phosphate.

Some nutrients are necessary to provide food for plants and, consequently, fish and other aquatic life. However, if the nutrient level becomes excessively high, overabundant and undesirable algae as well as other aquatic plant growths create nuisances. (Refer to Chapter IV for further discussion of this problem.)

The surveys revealed low nutrient levels in the Lake of the Ozarks. These levels are above the critical levels usually accepted as causes of algal and other plant growth. However, due to factors to be discussed in the succeeding chapter, no recommendation for treatment to remove nutrients from treated wastewater will be made at this time. Monitoring should continue and, if the levels increase and/or nuisances occur, remedial action should be taken.

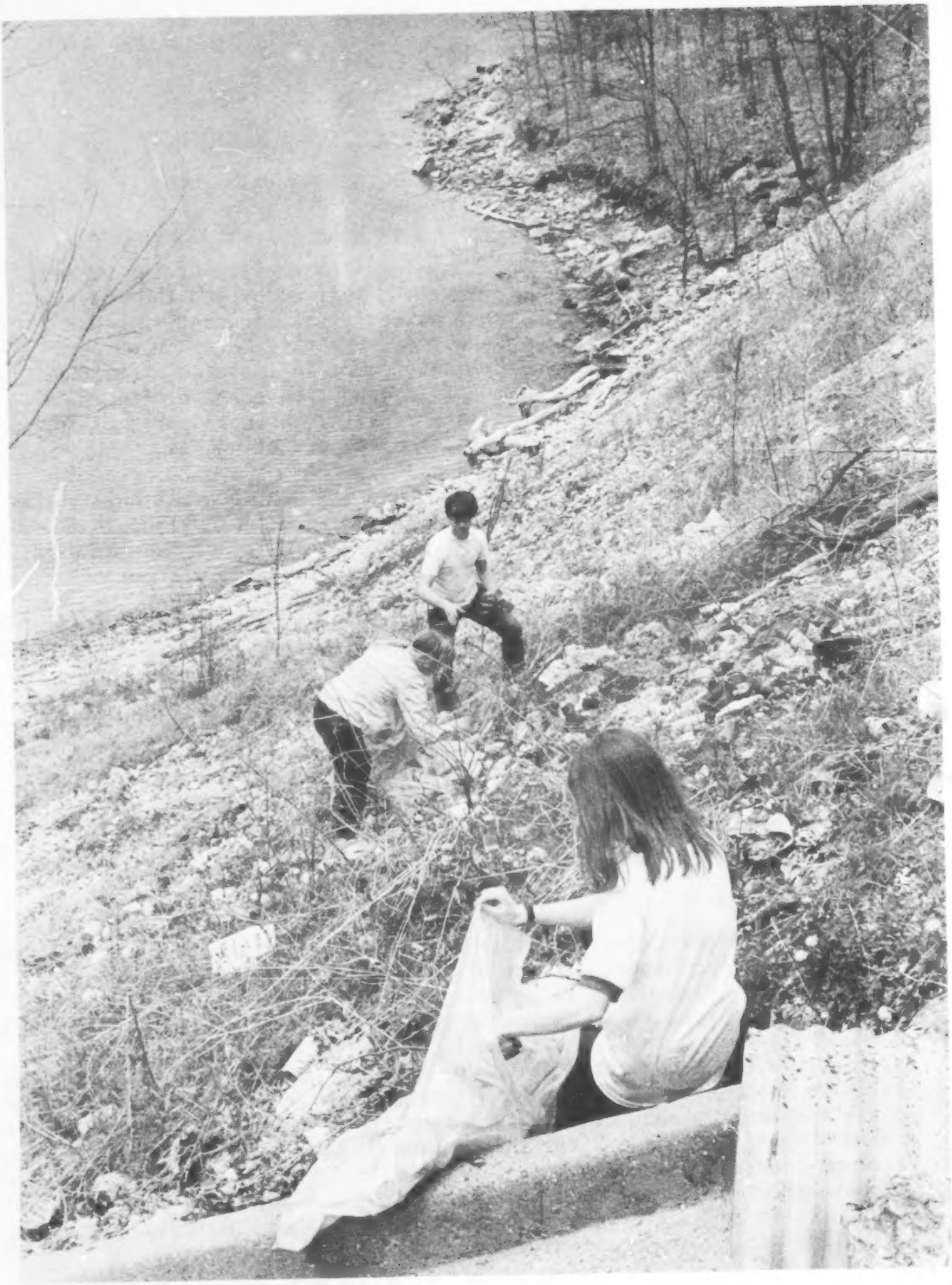
SUMMARY

The critical design factors recommended for the Lake of the Ozarks are:

1. One hundred gallons per capita per day (gpcd) with peak flows of 350 gpcd;

2. Strengths of 100 mg/l to 200 mg/l SS and BOD to be reduced to 20 mg/l SS and BOD by treatment;

3. Disinfection so that fecal coliforms are fewer than 200/100 ml. No nutrient removal is recommended at this time.



Volunteer Student Group (Students Tired of Pollution or S.T.O.P.) picking up trash along the Lake shores. (Photo by: Don Wooldridge, Missouri Department of Conservation)

CHAPTER VII

DESIGN CRITERIA

BASIC TREATMENT CRITERIA

Under a wastewater management system, the quality of the Lake of the Ozarks and its tributary streams must meet or exceed the water quality standards adopted for these waters. As discussed in other chapters, the quality of the Lake waters currently meets or exceeds adopted standards, with the exception of certain isolated areas during high use summer months. The anti-degradation section of current standards precludes lowering the water quality in those parts of the Lake where quality currently exceeds the adopted standards.

An effective wastewater management system must prevent any further degradation of the Lake waters and must elevate water quality in those areas now below standard to meet criteria. For this purpose, a basic treatment standard has been established which requires a treatment plant to produce an effluent containing a BOD strength lower than 20 mg/l (five-day BOD), and an SS lower than 20 mg/l. Standards established by the Missouri Clean Water Commission also require a fecal coliform count in "...waters designated for whole body water contact recreation..."[2] not to exceed 200 fecal coliform organisms per 100 ml of effluent.

For a complete list of other parameters, the reader is referred to the Water Quality Standards published by the Missouri Clean Water Commission.

NUTRIENT LEVELS

In establishing design criteria for a waste treatment plant discharging to a lake, an important area of consideration is that of nutrients or fertilizing elements. To prevent unwanted growth of algae and other aquatic vegetation, it is desirable to maintain levels of plant nutrients below critical quantities. The quality surveys of the Lake revealed nutrient levels are already above the critical point. However, with the relative volumes of the Lake and either present or projected inputs from waste treatment plants discharging to the Lake, as well as from the drainage basin area of the Osage River which drains to the Lake, any nutrient control or removal would have little or no effect upon nutrient levels. From a cost effectiveness or economic standpoint, nutrient removal cannot be justified in any waste treatment plant contemplated in the Lake area at this time or in the foreseeable future.

ALTERNATIVE SYSTEMS

The major design criteria for Missouri's sewerage systems and waste treatment plants are available in a publication, A Guide for the Design of Sewage Works,[3] distributed by the Missouri Clean Water Commission. This guide establishes and/or recommends minimum standards for design and operation of sewerage facilities. Although the publication generally covers all aspects of normally anticipated conditions in a rather detailed manner, it does not attempt to establish standards for relatively new or untried concepts. Since one of the alternatives reviewed for this report, a pressurized collection system, is such a concept, certain exceptions to the design criteria as published must be made.

Per capita flows under a pressurized collection system are only 50 gallons per capita per day, rather than 100. Laterals, submain, interceptor and trunk sewers will not be designed on the basis of handbook values, but on actual expected flows, such as the aforementioned 50 gallons per capita per day flow. These must be calculated and shown for each line, and the line properly sized to maintain a velocity of at least 2 feet/second. The minimum sized pipe--8 inches--specified in the guide, will be reduced to 1¼ inches. Since pumping is demanded at each connection, depth criteria no longer must anticipate basements. Slope, as such, has no meaning. Alignment between manholes must no longer be on tangent or straight lines. There will be no manholes in the true sense of the term. Since the line is pressurized, joints will not accept infiltration; any leakage is outward.

The system will function hydraulically as a pressurized water line with multiple pump inlets. Provision must be made for both pressure and vacuum relief valves. The entire section of the guide regarding pump stations and pumps will not apply to the pressure alternate. Under this concept, the project engineering report must cover specifications for the pumps and their installation in close detail. Pipe selection is not covered, but the pipe selected must be available in sizes designated in the report, and must carry the proper pressure rating. The pipe must also be capable of watertight connections under the expected pressure, and possess the necessary physical and mechanical characteristics of strength and durability.

Since the system requires electrical power at each user site, use of the pressurized alternate will necessitate close scrutiny of power availability and reliability. Although the reliability required under a conventional system is not demanded at each site, the alternate must meet a degree of reliability which will not inconvenience individual users for any length of time exceeding the normal storage or wet well capacity at each site. This is a function of the pump-grinder units selected.

TREATMENT SYSTEMS

Since the treatment plants to be discussed in Chapter VIII are conventional, a minor modification must be made: per capita flows will be on a basis of 50 gallons per capita per day rather than 100 gallons per capita per day, and solids content and biological strength will be nearly twice that normally expected.

If, after further study, a conventional system is selected rather than a pressurized collection one, the Missouri Clean Water Commission criteria for collection systems will apply.

CHAPTER VIII

WASTEWATER TREATMENT PLANT REQUIREMENTS

MUNICIPALLY OPERATED WASTEWATER SYSTEMS

In the Lake of the Ozarks Region, three cities currently own and operate wastewater treatment and collection systems--Warsaw, Camdenton, and Linn Creek. In addition to these urban systems, there are privately owned facilities in the Study Area which serve resort complexes, industry and homes. It is the intent of this chapter to summarize plant modifications necessary to ensure effluents from these systems are in compliance with the requirements of the Missouri Clean Water Commission.

WARSAW, MISSOURI

Warsaw is constructing a new three stage lagoon system with chlorination facilities. Projected completion date is 1974. However, the existing system does not serve the entire community. Approximately 200 of Warsaw's population of 1,407 are either using pit privies or on-lot septic tank systems which will be replaced by the new system. Designed for a population of 2,000, the plant is expected to meet the effluent requirements of BOD and SS not to exceed 20 mg/l and a fecal coliform count not to exceed 200/100 ml. Nutrient removal can be added, if necessary, at a later date.

The construction of Harry S. Truman Dam and Reservoir immediately upstream from Warsaw may cause flooding in and around the new lagoon facilities. The Corps of Engineers has agreed to construct a levee as necessary to protect the city's facilities.

CAMDENTON, MISSOURI

Camdenton has a sewerage system with lagoon treatment, but no disinfection facilities. As shown in Table IV-A of Chapter IV, samples taken in May, 1971 showed an effluent with values in excess of current requirements. The BOD was 28 mg/l and SS (termed nonfilterable solids) was 67 mg/l. No coliform data was taken since it was known that without disinfection the bacterial population exceeded the standards by several magnitudes.

The July 1971 survey revealed no discharge of effluent. This indicates evaporation of water from the lagoon surface exceeded inflow. In July of 1971, the operation exceeded the Missouri Clean Water Commission requirements.

Results of the study effort indicate the community should employ a consulting engineer to investigate two possibilities. One is the remodelling of the existing lagoon system, including installation of disinfection equipment to meet effluent standards. An alternate is the enlargement of the lagoons to balance inflow and evaporation and to include storage during months of low evaporation to prevent outflow. Some lagoon systems in Region VII currently operate in this manner. However, preliminary work by this office indicates the latter method would probably be the most costly. A sizeable capacity and surface area are demanded due to moderate annual rainfall and low evaporation rates in the fall, winter and spring months.

LINN CREEK

Linn Creek has no formally organized sewerage system or wastewater treatment plant. The town is served by many individual on-lot systems, consisting of pit privies and/or septic tanks which are privately owned. The Missouri Clean Water Commission lists Linn Creek as needing sewers and an associated wastewater treatment plant. To date, steps have not been taken in this direction. Until engineering surveys are made, reliable cost estimates cannot be determined. An investigation of the topography and presence of rock must be made. Possibilities for a plant site must also be explored.

An estimated first cost, based on areas with populations comparable to Linn Creek's 264,* is approximately $300,000. Annual maintenance and operational costs could be as high as $5,000, although such an estimate is preliminary due to the current instability of chlorine prices.

PRIVATELY OWNED COLLECTION AND TREATMENT SYSTEMS

Reconnaissance surveys indicate four privately owned systems serving single resort complexes. No data were collected on the smaller systems served by various treatment schemes. Treatment results are as variable as the schemes. Many of the smaller systems must be incorporated into larger ones with standard sewers and wastewater treatment plants.

Samples collected in May, 1971 and in July, 1971 at one of the larger privately owned systems (see Table IV-B, Chapter IV) showed high variability--SS (called nonfilterable solids) varied from 22 to 52 mg/l and BOD from 16 to 47, indicating poor operation and maintenance in addition to highly variable flows and loads. None of the systems had disinfection facilities. As indicated in Table IV-J and Table IV-K of Chapter IV, these effluents lowered the Lake quality below the bacterial standards of the Missouri Clean Water Commission. Remedial action is needed.

*1970 Population for Linn Creek.

It is recommended the owners of the existing systems at the four large complexes initiate actions to improve their operations, and disinfection facilities be added. Further surveys should be undertaken at the remaining private properties as a basis for providing systems which meet the Water Quality Standards.

SUMMARY

Two of the three communities need sewerage systems and either new or rehabilitated wastewater treatment works. All privately owned facilities require improved operation and disinfection. Many private lots, lands, and associated resort or commercial developments must have new sewerage systems and wastewater treatment facilities in order not to contravene the water quality and effluent standards established by the Missouri Clean Water Commission.

CHAPTER IX

ALTERNATIVE REGIONAL SEWERAGE PLANS

CHARACTERISTICS OF THE STUDY AREA

An aerial view of the Lake of the Ozarks Region indicates the scope of difficulty encountered in designing a sewerage system for the area. Extremely rough topography; Lake levels in relation to site development elevations; scattered, isolated cabins, residences and commercial establishments--all contribute to the technical difficulties of design. Further, areal geological profiles consist of either very rocky soils or massive layers of limestone which contribute to excessive costs for excavation or trenching.

Another difficulty, perhaps not apparent to the casual observor, is the political or administrative atmosphere. In the Ozarks Study Area, no official land use plan or zoning exists. The Region is largely unincorporated, with rural county administration. For the most part, land ownership consists of small cabin or commercial sites. No coordinated municipal services exist for fire and police protection, road and street planning, construction and maintenance, health and welfare assistance, or water supply facilities. If these exist at all, they are generally under the aegis of the county court (analogous to a board of county supervisors or commissioners, in most states).

This chapter concerns engineering or technical solutions to the topographical and geological problems. Legislation which might assist in a solution to administrative problems is outlined in Chapter XIII.

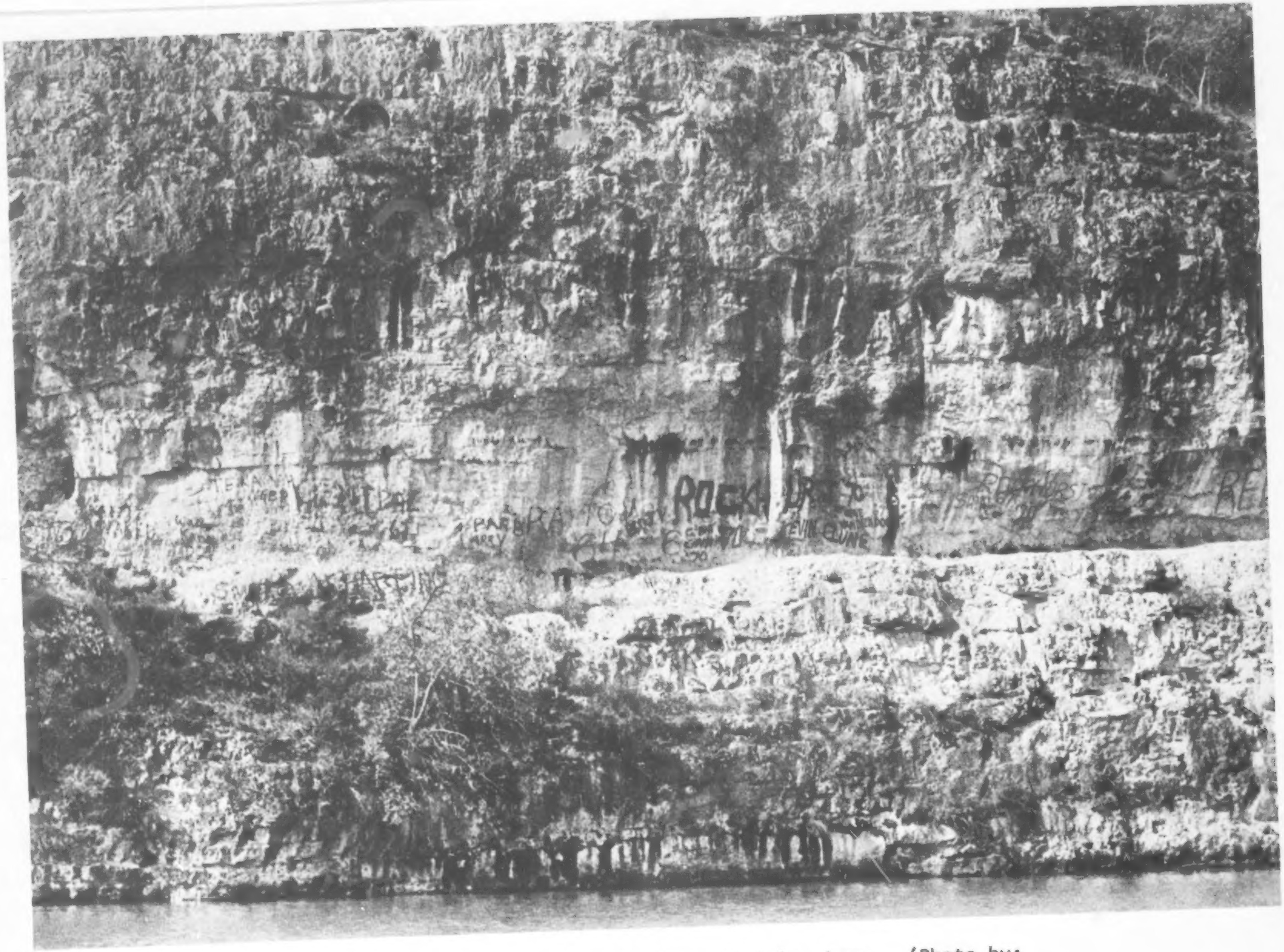
ALTERNATIVES

Conditions existing in the Lake of the Ozarks Area offer four possible alternatives for collection and disposal of sanitary wastewaters.

Alternative No. 1

The first possibility is to do nothing. What would be the consequences of such a failure to act?

Current surveys show certain arms or coves of the Lake are bacterially contaminated, and their use for whole body water contact recreation would, of necessity, be prohibited. If this condition were to continue, and not be corrected, growth or increased use would be banned. Onshore conditions due to leakage, spillage, or seepage from existing on-site (or on-lot) systems would remain unchanged. With time, these completely unsanitary and disease promoting conditions would inhibit residential growth as well



Close-up View of limestone bluff along the Lake shore. (Photo by:
Don Wooldridge, Missouri Department of Conservation)

as recreational use. The present conditions have resulted from the use of privies, septic tanks or cesspools with and without tile or leaching fields in soils poorly adapted for this use. The groundwater supplies must be receiving some of these wastewaters, although this is not documented in the study surveys. Considering economic, environmental, and health factors, the first alternative is unacceptable.

Alternative No. 2

The second alternative is a modification of the first. Due to the well-known or anticipated problems associated with collection and treatment of wastes in a central treatment plant, individual or on-site treatment facilities have been proposed. Such a system is possible.

Techniques and equipment are available for this management system. However, this type of management would result in conditions quite similar to existing ones due to:

1. Soil conditions;
2. Highly variable results from individual operation by each lot owner;
3. Overall costs;
4. Lack of strong central control or an administrative unit.

The adoption of this system would merely delay the necessity for introduction of another system for a few years.

Alternative No. 3

A third alternative is the use of conventional forms of sewage collection and treatment. The conventional sewerage collection system. is operated, for the most part, by gravity. Pipe sizes and grades are dictated so that oversized pipes handle the occasional oversized pieces of waste which, if not anticipated, lead to stoppages and clogged lines. Since the system is dependent upon gravity, lines quickly become deep and trenching, specially in the soils and rock in the area, becomes quite expensive. Maintenance demands straight lines with manholes at every change of direction or grade (slope) of the pipelines. This again leads to high costs and makes construction and maintenance difficult.

An investigation of this conventional system showed that, while it was technically feasible and could be built, costs would be three to seven times greater than those of a system built under normal or usual topographic, geologic, and demographic conditions. The excessive costs applied only to the collection system. The treatment works could be constructed at normal costs. If a conventional system is desired, this system can work sufficiently to meet the State's Water Quality Standards and public health requirements.

Alternative No. 4

The fourth method is a pressurized sewerage system. All sewers operate under pressure rather than by gravity and, in technical terminology, all sewers are force mains. The pressure is developed by a pump located at each house or commercial building which receives the flow from the house or building and pumps it into the pressure system. This eliminates the need for construction of a sewer in a uniform downhill slope for flow. The sewers can then follow the natural contour of the land, since the pressure developed by the pumps forces sewage through the pipe uphill and downhill. The sewers also can be constructed at a general uniform depth beneath the surface of the ground, greatly reducing excavation costs.

Use of a pressurized system allows considerable freedom in selection of sewer location. Sewers can be constructed almost entirely within street or road rights-of-way, eliminating any construction along the Lake shoreline necessary for gravity sewers.

The pump units also incorporate a grinder--all solids are finely ground, as in the typical home garbage grinder disposal units installed in kitchen sinks. This means that smaller sizes of pipe can be used. Also, since the system is pressured and closed, no extraneous large solids can enter the line and, therefore, design does not take this factor into consideration. A relatively inexpensive plastic pipe as small as 1¼ inches in diameter can be used, instead of a pipe of vitrified clay with a minimum diameter of 8 inches.

While few pressurized sewerage systems have been constructed, the concept has been intensively researched for the past 15 years. The first system was installed ten years ago in Kentucky. Several have been installed in New York and Indiana. There are many firms fabricating the system's pipe and fittings, and at least four companies producing the pump-grinder units. Therefore, securing material and equipment does not present a problem. Installation should present no problems. The plastic pipe and fittings have been generally used in the water distribution systems, and no unusual problems have occurred.

On the basis of current estimates, this system can be constructed, operated, maintained, and administered for approximately one-third the cost of a conventional system in the Lake Region.

Treatment of wastes will be discussed in a following chapter. Regardless of the type of sewerage system selected, the treatment requirements will be the same, and the available treatment methods can process the wastes from either conventional or pressurized sewerage systems.

CHAPTER X

TREATMENT AND DISPOSAL OF WASTES

TREATMENT METHODS

A treatment method for a wastewater management program in the Lake of the Ozarks Area must be efficient--both cost-wise and in removal of unwanted constituents, readily operated with a minimum of expertise and manpower, reliable, reasonably durable, and designed to blend aesthetically with the landscape.

Almost without exception, the wastes generated in the Lake Area will be domestic or normal sanitary wastes. The area's few commercial establishments, present and projected, will also generate only sanitary wastes. No trade or industrial wastes will be produced in the service area of the proposed management plan.

Characteristics of sanitary or domestic household wastes are well documented and relatively constant in composition and quantity. In conventional sewerage systems, expected sewage flow is approximately 100 gallons per capita per day, with about 1/6 to 1/4 pound of dissolved and suspended solids. These solids demand approximately 1/6 to 1/4 pound of oxygen per day (BOD) to reduce obnoxious organic matter to relatively harmless inorganic matter. With this solid matter are many types of bacteria and viruses, some having disease producing or other undesirable characteristics.

The proposed collection system--a tight, pressurized one--excludes all external or extraneous sources of water normally found in sewerage systems. Because of the system's tightness, subnormal flows occur. Collection systems using the pressure concept deliver a waste volume of from 50 to 60 gallons per capita per day, with approximately the same solids content and the same oxygen demand as sewage from conventional systems. Of course, the bacterial and viral counts remain approximately the same. In other words, the proposed collection system delivers a waste almost twice the strength of a conventional one. In choosing a treatment method, this reduced water volume and resulting greater solids content must be considered.

Three general treatment schemes were investigated: lagoons, the trickling filter process with a polishing lagoon, and the activated sludge process.

Lagoons

Lagoons have many advantages. They require a minimum of manpower and expertise and are reliable and efficient in operation. In addition, they are not detrimental to the landscape. However, lagoons have some disadvantages. Greater land area is required, and the soil profile must generally be impervious to retain the water and wastes for a required time period as well as to prevent leakage and resulting pollution of groundwater. In addition, lagoons attract many species of waterfowl which come into close contact with the wastewater and fly to nearby Lake waters, possibly carrying unwanted bacterial and viral elements into other areas of the Lake. Hunters sometimes take these birds before sufficient time lapse or washing removes contaminants from them.

The lagoons would occupy Lake front sites which are considered very valuable. Geological studies reveal soils and underlying rock formations of these sites are extremely permeable. Therefore, additional expense would be necessary for adequate waterproofing of the lagoon floor and levees.

Results of lagoons in reducing bacterial and viral numbers are generally good, but the extent of their reliability or dependability is not so great that their use alone would produce results required in the Lake waters. Therefore, considering the land costs, waterproofing expenses, and the problems of wild life and disinfection, use of lagoons is not recommended for the Lake of the Ozarks Area.

Trickling Filter Process

The trickling filter process has some advantages over use of lagoons, for several reasons. Among these are the construction of units from concrete, steel or plastics, so leakage or seepage create no problems, in addition to smaller land requirements. While demanding greater maintenance and closer supervision than lagoons, the trickling filter process is considered very reliable.

A trickling filter plant could be built on a small lot, easily camouflaged or blended into the landscape through use of paint and plantings. No problems with animal or bird life would exist. However, without an auxiliary process, trickling filter systems cannot generally produce the high quality effluent required. The additional process usually involves use of a small lagoon. Although this would not pose as great a problem as the lagoon system discussed previously, some problems would arise. Again, disinfection, probably with chlorine, is necessary.

Considering costs, trickling filter systems are much more expensive than lagoons in first, or capital costs. Maintenance and operating costs are also greater. While requiring less land, the trickling filter system would have high total costs, thus making selection of this process unfeasible.

Activated Sludge Process

The activated sludge process requires much less space than either the trickling filter system or lagoons. When properly operated, the process produces the best effluent of any conventional treatment system. No auxiliary processing is needed to produce an effluent to meet the Missouri Water Quality Standards for the Lake of the Ozarks. The plant can be almost completely prefabricated and installed with a minimum of landscape disturbance. It blends aesthetically with the landscape, due to its small size, minimum of site dirt movement required, and absence of buildings or structures above ground level. The entire plant could occupy the backyard of a conventional lot.

Plants are available to treat highly fluctuating daily flows. This is an advantage, since recreational developments are subject to severe load changes on weekends or during seasonal uses or demands. Disinfection equipment is available for all prefabricated plants.

The activated sludge process costs less to install, but operation and maintenance costs are greater than those of other systems. Relatively higher levels of expertise are required than for either lagoons or trickling filters. Employment of operators with this expertise is possible, but at additional costs.

SUMMARY

To conclude, the selection of an activated sludge process is recommended because of the high quality effluent possible, the relative ease of installment and operation, the disinfection process, the small land area required, and the relative ease of blending the plant with the local landscape. Although first costs are the lowest of the alternates, the maintenance and operation costs are highest. Overall costs, including those for land, equipment, construction, maintenance and operation, debt retirement and wages, are almost equal for trickling filter systems and activated sludge processes.

However, because of the higher quality effluent produced, activated sludge is recommended. Lagoons are not recommended as an alternate method for the Lake of the Ozarks Area because of the amount and location of land required, difficulty in blending into the recreational scene, costs and problems in waterproofing, and difficulties in disinfecting the effluent.

CHAPTER XI

RECOMMENDED REGIONAL PLAN

WASTEWATER COLLECTION AND TREATMENT SYSTEM

Previous chapters discussed requirements for effluents discharged to the Lake, wastewater treatment systems which produce such effluents, and feasible systems for collection and transport of raw wastes from homes and commercial establishments to treatment plants. In this chapter, a wastewater collection and treatment system is proposed for the Lake of the Ozarks Region.

Collection System

A pressurized pipeline system is recommended for collection and transportation of the wastes and wastewater. This system receives wastes and wastewater from each building or building site by means of a combination pump and grinder unit operated by electrical energy provided by the building occupant. This, of course, means each dwelling unit, resort or commercial building is connected to a source of electrical power, or is capable of generating its own electrical power. The site owner, or tenant, is responsible for electrical input operational costs. Maintenance and first costs will be paid by the administrative unit, since the type of equipment which performs the input function must be under the direct control of the administrator.

Maintenance and/or replacement must also be carried out by the administrator to ensure proper operating of the entire system. The power demanded for input is not much greater, if any, than that normally demanded by a common family dwelling unit. Power reliability at the input unit also is not much greater than that demanded by a householder. Construction, operation and maintenance of the pipelines and appurtenances are the complete responsibility of the administrator.

Treatment Plant

The treatment plant uses the contact stabilization type of activated sludge system, with the provision the plant can easily be modified to the extended aeration type of activated sludge at the low off-peak non-recreation seasons.

After treatment, the effluent will be disinfected by means of either a gas chlorinator or a liquid hypo-chlorinator. Either method will disinfect the effluent to the required standard.

Summary

To reach the above conclusion, a detailed study of a 69.6 mile segment of the Niangua Arm of the Lake of the Ozarks was made. This segment is quite representative of social, topographic, and geologic conditions in the overall Lake area. Further evidence supports the fact the recommendations can be applied anywhere on the Lake shoreline and on any other large lake with similar topographic and geologic conditions.

The major constraint, in the past and present, has been the first cost of the collection system in an area such as the Lake of the Ozarks. The investigation revealed the most feasible system was one with treatment plants located not farther than approximately 20 miles apart, measured generally by shoreline or pipeline (not airline or straight line distance). This means, essentially, that the greatest distance between the treatment plant and a connected building, as measured along the pipeline, will not exceed 10 miles. This spacing of plants is dictated by pumping costs and is dependent upon available equipment and pipeline diameter. Due to the type of material available for manufacture of the pipes, economy is lost when larger sizes are necessary.

One segment of the proposed system selected as a representative or average for the process has approximately 15 miles of pipeline, consisting of 15 lines ranging from 1,000 feet to 12,000 feet. This serves 377 residences and 122 commercial sites. The treatment plant for this segment can process and discharge nearly 70,000 gallons per day.

In succeeding chapters, costs and legal administration for the proposed system will be discussed.

CHAPTER XII

BASIS OF COST ESTIMATES

SUMMARY

The pressurized sewerage process was selected as the most effective wastewater collection system on the basis of total monthly cost to users. This cost consists of first or construcation cost (including engineering design), interest on debt incurred, operation, maintenance and administration of the system. Two acceptable alternatives were discussed in Chapter IX: a pressurized collection system and a gravity system, both with the same type of treatment plant. Effluent discharged from both plants would be of the same quality, regardless of the type of collection system employed. Due to the tight pipelines required for the pressurized system, the quantity of flow could be 50 percent lower than that from the gravity system.

Treatment Plant

Research showed savings could be made in sizing of the treatment plant and quantities of disinfectant. For example, one segment, if designed as a conventional gravity system, would demand a plant capability of 137,500 gallons per day. The plant with a pressurized system could be designed for 86,000 gallons per day, according to data collected during this study.

Collection System

However, the major savings is a result of the collection system. Preliminary designs and cost estimates of components and labor were reviewed in reaching this conclusion. Use was made of the findings of an independent investigator concerning the feasibility of a pressurized versus gravity system. The consultant was employed by a client faced with problems similar to those of the Lake residents.

The Niangua Arm of the Lake studied by the Environmental Protection Agency revealed 1,628 home sites and 656 commercial sites. The area studied by the consultant had about 240 home sites with no commercial sites mentioned. It was decided comparisons were possible without great adjustment for economies of scale. The consultant's estimates were based on 1972 prices for materials and labor in the Kansas City, Missouri area. From cost surveys filed in EPA's regional office, expectations were labor costs in the Lake Region would be somewhat lower, but material costs due to transportation problems would be somewhat higher, with overall costs comparable.

The consultant showed that the collection system cost for 240 home sites, exclusive of engineering, legal and administrative costs, was approximately $3,200 per site, or approximately $800 per capita. Using cost curves derived several years ago by EPA and adjusted through Engineering News Record and EPA indices to 1973 costs, researchers arrived at a per site cost of approximately $2,070 (or about $520 per capita). These costs are to be compared with $6,620 per site ($1,655 per capita) for a gravity system as computed by the consultant. In addition to the lower cost of a pressurized collection system, the smaller treatment plant would result in savings.

The operation and maintenance costs were estimated at $60 per year per site for the gravity system, and at $100 per year per site for the pressurized system. Increased maintenance and operation costs do not nullify the savings in first cost. Since the gravity system also requires some pumping, availability and reliability of the area's electrical power is the same in either case.

Both the cost calculations and the consultant's report referred to above are on record in the Environmental Protection Agency's Regional Office. This information will be published in an appendix to this study at a later date if there is a demand for more detailed data.

A summary of costs for the recommended system and estimates of monthly charges per site or user are presented in Chapter XIV.

ADMINISTRATION OF RECOMMENDED PLAN

ALTERNATIVE ORGANIZATIONAL PLANS

Some organizational alternatives for a regional sewerage system for the Lake of the Ozarks Region are:

1. A new, single purpose sewer district with jurisdictional responsibility for area-wide operation.

2. A multi-purpose single agency (e.g., regional planning commission) to plan and advise the various political subdivisions concerning related programs of solid waste disposal, water and air pollution, land use regulations, etc.)

3. A single existing agency, contractually serving all voluntary participants in a regional system.

4. Joint ownership and operations region-wide, with a multi-purpose regional agency to plan and coordinate activities for the entire geographical area, and with operational control in areas where no other jurisdiction is feasible.

5. Joint operations by the largest existing operational agencies which contractually serve all other participants.

RECOMMENDED SEWER DISTRICT PLAN

Of the available alternatives, the most advantageous would be the single purpose sewer district with jurisdictional responsibility for area-wide operation.

Specific statutory authority to organize such a district is provided by House Bill No. 625, enacted by the 77th General Assembly of the Missouri Legislature. A copy of the bill follows this chapter.

Vernon's Annotated Missouri Statute 204.250 provides that the area may be established and incorporated as a common sewer district if:

1. A county of the second, third or fourth class with a natural drainage area contains all or portions of several drainage basins, municipalities or sewer districts.

2. A common sewer district encompassing the entire area would be eligible for federal aid and assistance under the provisions of Title 33, Section 1151, et seq., of the United States Code Annotated, as now or hereafter amended.

The establishment and incorporation of the sewer district under V.A.M.S., Sections 204.250 and 204.470, should take place in the following manner.

The county court, with the concurrence by resolution of the legislature of the county wherein the major portion of the area lies, may petition the circuit court with jurisdiction over the area's major portion for the appointment of commissioners as herein provided; and the circuit court shall take further action as necessary for the submission to the legal voters residing in the area the question whether the area shall be organized and incorporated as a common sewer district.

The petition shall set forth a description, in general terms, of the territory to be embraced in the proposed sewer district, suggest a name for the proposed common sewer district, and state the aim and purposes for which the district is created.

In all first, second, third and fourth class counties, the county court, by resolution, shall appoint five trustees, the majority of these to reside in the district. A member of the county court shall be among the five appointed trustees. In the event the district extends to any county bordering the county in which the greater portion of the district lies, the presiding judge of the adjoining county shall be an additional member of the appointed board of trustees. The board of trustees shall be responsible for the control and operation of the sewer district.

As a general rule in statutory construction, when a specific means of accomplishing a certain purpose is set forth by statute, this precludes the use of any general or implied methods of accomplishing such a purpose. The provisions of the statute as outlined above provide the specific method for organizing a common sewer district. Any other method would be precluded by judicial interpretation.

FIRST REGULAR SESSION
[TRULY AGREED TO AND FINALLY PASSED]

HOUSE BILL NO. 625

77TH GENERAL ASSEMBLY

AN ACT

To repeal section 249.450, RSMo 1969, and sections 204.250 and 204.300 of House Committee Substitute for House Bills Nos. 1239 and 1300, enacted by the Seventy-sixth General Assembly, Second Regular Session, and approved by the governor on April 20, 1972, relating to the establishment of sewer districts, and to enact in lieu thereof three new sections, relating to the same subject.

Be it enacted by the General Assembly of the State of Missouri, as follows:

Section 1. Section 249.450, RSMo 1969, and sections 204.250 and 204.300 of House Committee Substitute for House Bills Nos. 1239 and 1300, enacted by the Seventy-sixth General Assembly, Second Regular Session, and approved by the governor on April 20, 1972, are repealed and three new sections enacted in lieu thereof, to be known as sections 249.450, 204.250, and 204.300 to read as follows:

249.450. 1. In any county having not less than five hundred thousand and not more than seven hundred thousand inhabitants, in any county which adjoins or which contains a portion of a city having more than four hundred thousand inhabitants, and in any county of the first class not having a charter form of government, whenever a petition signed by a majority of the owners resident in a part of such unincorporated residence district is filed with the county clerk of any such county, or whenever such county court deems the construction of sewers necessary for sanitary or other purposes, such county court after consultation with the sewer engineer shall adopt a resolution to establish such sewer district or districts. The resolution shall describe generally the size and location of the proposed sewer district or districts.

2. In any county of classes two, three or four which are not subject to subsection 1, the county court of the county, upon the filing of a petition signed by a majority of the owners of real estate in the proposed district, shall, after consultation with the sewer engineer, adopt a resolution to establish the sewer district. The resolution shall describe generally the size and location of the proposed sewer district.

204.250. 1. If the construction and maintenance of a common system of trunk sewers and sewage treatment plants is necessary to secure proper sanitary conditions for the preservation of public health in a natural drainage area the major portion of which lies within a county of the first class containing all or part of a city having a population of four hundred fifty thousand or more, or in a county of the first class not having a charter form of government, or in a county of the second, third or fourth class, and which natural drainage area contains all or portions of several drainage basins, several municipalities or sewer districts, and if a common sewer district encompassing the entire area would be eligible for federal aid and assistance under the provisions of Title 33, Section 1151 et seq. of the United States Code Annotated, as now or as may hereafter be amended, the area may be established and incorporated as a common sewer district under sections 204.250 to 204.470 in the following manner: The county court, or in charter counties, the county executive with the concurrence by resolution of the county legislature, of the county within which the major portion of the area lies may petition the circuit court having jurisdiction over the major portion for the appointment of commissioners as herein provided, and to take further action as may be necessary for the submission to the legal voters residing in the area of the question whether the area shall be organized and incorporated as a common sewer district under sections 204.250 to 204.470.

2. The petition shall set forth a description in general terms of the territory to be embraced in, suggest a name for the proposed common sewer district and state the aim and purposes for which the district is created.

204.300. 1. In all first, second, third or fourth class counties the county court by resolution shall appoint five trustees, the majority of whom shall reside within the boundaries of the district. A member of the county court shall be among the five appointed trustees. In the event the district extends into any county bordering the county in which the greater portion of the district lies, the presiding judge of the adjoining county shall be an additional member of the appointed board of trustees. The board of trustees shall be responsible for the control and operation of the sewer district. The term of each board member shall be five years; except that, county judges sitting upon the board shall serve no longer than the expiration of their term. The first board of trustees shall be appointed for terms ranging from one to five years so as to establish one vacancy per year thereafter. The trustees may be paid reasonable compensation by the district for their services; except that, any compensation schedule shall be approved by resolution of the county court or county legislative body. Any and all expenses incurred in the performance of their duties shall be reimbursed by the district.

2. The board of trustees shall have power to employ and

fix the compensation of the staff as may be necessary to discharge the business and purposes of the district, including clerks, attorneys, administrative assistants, and any other necessary personnel. The board of trustees shall appoint the sewer engineer for the county in which the greater part of the district lies as chief engineer for the district, and the sewer engineer shall have the same powers, responsibilities and duties in regard to planning, construction and maintenance of the sewers, and treatment facilities of the district as he now has by virtue of law in regard to the sewer facilities within the county for which he is elected. If there is no sewer engineer in the county in which the greater part of the district lies, the board of trustees may employ a registered professional engineer as chief engineer for the district under such terms and conditions as may be necessary to discharge the business and purposes of the district.

3. In any first class county having a charter form of government and containing all or part of a city having a population of four hundred fifty thousand or more, there shall be a three member board of trustees to consist of the county executive and two members of the county legislature to be appointed by the county executive, with the concurrence of the county legislature. One appointee from the county legislature shall reside within the sewer district. In the event the district extends into any county bordering the county in which the greater portion of the district lies the presiding judge or county executive of the adjoining county shall be an additional member of the board of trustees. The board of trustees, in addition to the powers set forth in subsection 2 of this section, shall have the power to employ a registered professional engineer as chief engineer for the district under such terms and conditions as may be necessary to discharge the business and purposes of the district.

CHAPTER XIV

FINANCIAL PROGRAM

PROPOSED PROGRAM

The engineering design of the facilities must be completed prior to determination of revenue requirements. Once the design is approved, cost figures for construction, operation, maintenance, and administration can be calculated.

The source of revenue recommended is that of revenue bonds. The bonds would be advantageous for the following reasons:

1. Only four-sevenths of the vote is required for approval.
2. Revenue bonds are retired by actual users.
3. Higher interest rate of revenue bonds makes them more desirable to investors.

To help retire the bonds, a connection fee for initial hookup of users to the system, plus a monthly service fee, could be charged. Once the revenue bonds are retired, the monthly service fee could be reduced to cover only the operation and maintenance costs of the system.

GENERAL DISCUSSION

All costs incurred in the formation of water and/or sewer districts must be considered in planning for financing. The following are the most obvious costs:

1. Administrative
2. Land
3. Construction
4. Operation and Maintenance
5. Debt Service (Interest)

The administrative costs will cover the formation and overhead of a board of trustees for the sewer authority. The board must oversee all phases of the construction, operation, and maintenance of the facilities. Consequently, administrative costs will last throughout the life of the system.

Financing of a sewer facility is usually accomplished through one or more of the following methods: general obligation bonds, revenue bonds, special assessment, or federal government loans and grants.

General Obligation Bonds

The Statutes of the State of Missouri require the approval of the voters of the district or authority before bonds can be issued for construction or improvement of a sewerage system. General obligation bonds require a two-thirds vote for approval and revenue bonds, a four-sevenths vote. Rules governing election and issuance of bonds are enumerated in Chapter 250 of the Missouri State Statutes.

General obligation bonds are retired through direct taxation of the locality in which the facilities exist. These bonds can be considered a more favorable means of financing, due to the comparatively low interest rate. However, they are limited by the general indebtedness a politically incorporated body may incur. Use of these bonds is also limited by the revenue generating capacity of the area, determined by the total assessed land value. If the general assessment is low, the amount of General Obligation Bonds which can be sold will also be limited.

Revenue Bonds

In contrast, revenue bonds are limited by neither the area's tax generating power, nor its general indebtedness. Revenue bonds are retired by revenue produced through use of the facilities. The residents using the system are those who pay for it. The only limitation is the potential number of users the facility will accommodate, since the capacity of the system will determine the revenue generated.

Revenue bonds are often more marketable because investors are attracted by the interest rate which is higher than that for general obligation bonds. Retirement of revenue bonds through fees paid for use of the facilities makes these bonds a more logical method of financing in areas with little tax potential. Another desirable feature is that only four-sevenths of the voters' approval is required for bond passage (compared with two-thirds for general obligation bonds).

Special Assessment

Special assessments on property to pay for facilities have proven in the past to be more costly and are less favorably accepted by residents. Assessments are levied on abutting and/or benefiting property owners who then may pay the assessment in one lump sum, or in equal payments over a specified period. As in the case of general obligation bonds, the population involved can be a limiting factor in the use of special assessments. In areas with small populations or the inability to support a heavy tax, special assessments become even more undesirable as a method of financing.

Federal Assistance

Some federal assistance, in the form of grants, is available for the development and construction of water and sewerage facilities. Grants will provide assistance, but will not pay the entire cost of any project.

Survey Description of Study Area

The Study Area is located on the Niangua Arm of the Lake of the Ozarks, southwest of Camdenton, Missouri. The area lies within, but does not comprise entirely, the following survey descriptions: Section 34, Township 38, Range 17 and Section 3, Township 37, Range 17. Some of these lands have been partially subdivided and are known as the Lake Valley Estates and the Sunny Slope Subdivision and Additions. The remaining portion not subdivided is individually owned. The area is served by Lake Road 45-79, south from Highway 54 at the west end of the Camdenton Bridge. Approximately 233 acres of land are included in the Study area.

Land use in the Study Area consists largely of residential dwellings, with both permanent and seasonal residents. Land which is not subdivided is forest and open field, with a small portion used for cattle grazing. The area is mainly private-residential, and there is no indication this will change in the future.

Land Development and Population Projections

Development should continue in the present direction of residential expansion along the Lake shoreline. The growth trend in developed areas can be applied to the entire Lake area.

Approximately 100 dwellings exist in the area at the present time. Allowing three and three-tenths persons per dwelling would result in an estimated population of three hundred and thirty. There are 30 dwellings on lakefront property with a resulting 99 people, and 70 dwellings on non-lakefront property with an estimated 230 people.

The Lake of the Ozarks Region contains approximately 233 acres, with approximately 40% of it subdivided. The remaining 60% (140 acres) of non-subdivided land will be projected in this chapter as far as future subdivision and dwelling development.

Projections of land development and population are based on the following assumptions:

1. That a water and sewer district will be formed on the Niangua Arm of the Lake of the Ozarks.

2. That development will be in the form of residential dwellings, excluding any commercial development.

3. That assessed evaluation will be in the form of 1972 dollars; according to 1972 assessments, the average developed lot assessment is $1,000.

4. That number of people per dwelling will be three and three-tenths.

5. That 75% of the presently plotted lots will be developed in five years and 100% of those lots will be developed in ten years.

6. That the minimum 20 year development will be the additional subdivision (into 60 feet x 125 feet lots) and development of the first and second tier lakefront lots along the remaining one-fourth mile lakefront property, and the maximum development will be four tiers along the same lakefront stretch.

Based on the above stated assumptions, the following developments are anticipated:

1. Five Years - Development of 275 of the presently 368 plotted lots, with a resulting population of about 900.

2. Ten Years - Full development of the present 368 lots with a population of about 1,100.

3. Twenty Years - Full development of an additional 84 lots along the lakefront property, resulting in a total of 452 lots, with a population of about 1,500.

Land Assessment Values

Land assessment values of the Study Area were obtained from the Camden County Assessor's Office. Values for all but four lots of the entire area were available, and a relatively complete assessment appeared to be compiled. Assessments are as follows:

Entire Study Area	$213,795
Subdivided lakefront property	94,210
Subdivided non-lakefront property	85,585
Average subdivided lakefront lot assessment	719
Average subdivided non-lakefront lot assessment	433
Average assessment all subdivided lots	534

If development occurs as previously outlined, the assessed valuation of the area as it develops can be projected:

1. Five Years - 275 Lots - $275,000(Based on $1,000 assessed valuation per developed lot.

2. Ten Years - 368 Lots - $368,000) Based on $1,000 assessed valuation per developed lot.
3. Twenty Years - 452 Lots - $452,000)

Since the assessed value of the land involved is only $213,795, the lot and population density are not of sufficient size to support Government Obligation Bonds. Nor does there appear to be sufficient citizen support for a special assessment. Consequently, revenue bonds appear to be the most feasible method of paying for the construction of sewer facilities. In addition to revenue charges for the use of these facilities, a hookup fee might be used to help retire the bonds. A lower hookup fee charged during construction of the system is often used to encourage early hookup. This facilitates overall construction and, at the same time, encourages more users.

PROJECT CONSTRUCTION, OPERATION AND MAINTENANCE COST ESTIMATES

The following is an estimate of the costs which will be incurred in furnishing wastewater collection and treatment services for the Niangua Arm of the Lake of the Ozarks. As discussed previously, segments were selected so that no sewers were longer than ten miles, with treatment plants spaced about twenty miles apart (shoreline or sewer pipe measurement). The segments and relevant data are described further in the balance of this chapter.

Segment No. 1 - Little Niangua, south side, Section 6 to confluence with Niangua; Niangua, west side, headwaters to confluence with Little Niangua.

Segment No. 2 - Little Niangua, north side, Section 6 east to confluence with Niangua; Niangua, west side, to confluence with Little Niangua to mouth.

Segment No. 3 - Little Niangua, north side, headwaters to Section 31; Little Niangua, south side, headwaters to Section 1.

Segment No. 4 - Niangua Arm, east side, headwaters to Section 20.

Segment No. 5 - Niangua Arm, east side, Section 8 to mouth (Section 35).

POPULATION (SUMMER MONTHS)

Segment No.	Residences	Commercial	Total
1	1,569	228	1,797
2	1,035	370	1,405
3	315	130	445
4	1,131	244	1,375
5	834	340	1,174
	4,884	1,312	6,196

USERS (OR CONNECTIONS)

Segment No.	Residences	Commercial	Length
1	523	114	18.3 miles
2	345	185	12.0
3	105	65	6.2
4	377	122	14.9
5	278	170	18.2
	1,628	656	69.6

COSTS (EXCLUDING LAND)

Segment No.	Complete Collection System	Treatment Facilities
1	$1,296,590	$245,000
2	858,790	165,500
3	436,265	111,000
4	1,058,000	220,500
5	1,080,000	207,000
	$4,729,645	$949,000

RECAPITULATION

Total Construction Costs - $4,729,645 + $949,000 =	$5,678,645
Engineering @ 6.5%	369,112
Contingencies @ 2.7%	153,323
Administrative @ 0.01%	600
Legal @ 0.20%	11,357
Sub-Total	$6,102,037
Land (Treatment facilities only; it is felt line easements should be obtained at no cost)	62,500
Total	$6,164,537

COST ALLOCATION

It is believed existing federal and state legislation can make the following allocations a possibility:

Project Costs Eligible	$6,102,037
Less State Grant (15%)	- 915,306
Less Federal Grant (75%)	-4,576,528
Balance to be financed locally	610,203
Plus Land Costs (100% local share)	+ 62,500
Total Local Share	$ 672,703

LOCAL DEBT AMORTIZATION

Assume revenue bonds (recommended means of financing), with repayment period of 20 and 30 years and rates of interest at 5, 6, or 7 percent.

The bond issue could consist of one of the following sums:

$675,000 - Bonds are usually issued in denominations of $1,000 or $5,000.

$700,000 - Simply rounding to nearest $100,000.

$841,000 - Initial cost plus 25% reserve.

ANNUAL PAYMENT ($)

Face Value	20 Years			30 Years		
	5%	6%	7%	5%	6%	7%
$675,000	54,164	58,850	63,715	43,910	49,038	54,396
700,000	56,170	61,029	66,075	45,536	50,854	56,410
841,000	67,484	73,322	79,384	54,708	61,098	67,773

ANNUAL OPERATION AND MAINTENANCE COSTS

Segment	Cost
1	$18,753
2	11,054
3	7,304
4	11,252
5	10,265
Sub-Total	58,628
Administration @ 10% (Billing, Payroll, etc.)	5,863
Total	$64,491

TOTAL LOCAL COSTS

Capital debt retirement based on a low of 5% for 30 years and a high of 7% for 20 years.

	5/30		7/20
Annual Debt Retirement	$ 43,910		$ 79,384
Maintenance and Operation	58,628		58,628
Administrative Costs	5,863		5,863
Range of Annual Total Costs	$108,401	to	$143,875

Total number of users (dwelling unit or equivalent)	2,284

Annual Costs Per Unit Per Year

Low $108,401/2,284 = $47.46
High 143,875/2,284 = 62.99

Or on a per month basis and with householder or owner bearing on-site power costs of about $1.50/month.

Low $47.46/12 + $1.50 = $5.46
High 62.99/12 + 1.50 = 6.75

It appears that a sewer district, formed under House Bill No. 625, 77th General Assembly, Second Regular Session, of the State of Missouri, employing the revenue bond method of financing, can provide wastewater collection and treatment to ensure the protection and improvement of the Lake of the Ozarks Area.

REFERENCES

1. Corps of Engineers, U.S. Department of Army, Engineer District, Kansas City, Missouri; Harry S. Truman Dam and Reservoir Environmental Statement; January, 1973.

2. Missouri Water Pollution Board; Water Quality Standards, Osage & Gasconade Rivers and Tributaries - Osage-Gasconade River Basin, Missouri River Basin; Undated.

3. Missouri Clean Water Commission; A Guide for the Design of Sewage Works, Chapter 20, Paragraph 21; Undated.